Neural network classification of aviation personnel as an element of the information and control space for the security of a transport infrastructure object

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Abstract. The following article considers the development of a neural network assessment program for the level of readiness of aviation security personnel to carry out professional activities. The collection and preparation of initial data for training a neural network were carried out, a neural network was studied in the MATLAB system to assess the level of readiness of aviation security personnel to perform professional activities. As a result of the study, it was found out that the neural network provided precision 100%, recall — 97.4%, specificity — 95.9%. The dialogue program for assessing the competencies of aviation security personnel has been developed, based on the neural network parameters obtained in the MATLAB system in C++.

1. Introduction
Aviation security [1, 2] as a scientific direction deals with the issues of ensuring the protection of civil aviation from unlawful interference in its activities. The target functionality of the system that solves these problems is significantly different in content from other systems in the aviation transport system, which determines the specifics of the means, methods and procedures used in aviation security.

Throughout the history of the emergence and development of civil aviation, there is a problem of the human factor. The human factor today is the cause of more than 80% of aviation accidents and covers almost all aspects of production activities in civil aviation [3]. The modern concept of aviation infrastructure safety management includes the task of aviation personnel management. An important task of aviation security personnel management is the periodically conducted assessments of the level of personnel readiness to perform professional activities. The task is posed as the classification of personnel into satisfying and non-satisfying requirements based on the results of checking the competencies of personnel. The employee reviewer assigns points to each requirement of each competency on a ten-point scale. The final assessment of the specialist's readiness to perform his duties is also given. The final assessment of an employee's suitability for performing professional activities is not determined by the sum of points, minimum score, etc. The assessment considers the importance of the competence, the general impression of the expert from the answers, and other factors (maybe even the impression of the expert). Evaluating the suitability of an employee is a difficult task. At present, various analytical solutions for personnel management are known (People Analytics and Workforce Analytic) [4]. People Analytics and Workforce Analytic provide in-depth analysis of employee personal
characteristics for HR management. In our case, the task is a binary classification of personnel into ready and not ready workers for professional activities. The original data are numeric values. Fully connected neural networks are effective for solving these problems [5]. Therefore, it was proposed to use neural network classification to support the work of experts.

2. Preparation of initial data
Before constructing the neural network, it is necessary to form the training set. This is a set of training examples containing features that describe individual objects and target variables, labels. In order to solve the problem, the signs should characterize the degree of readiness of specialists to perform their functions, and the target value should characterize the final assessment of the specialist's suitability. To assess the level of readiness of aviation security personnel to carry out professional activities in accordance with the requirements of the Federal system for training personnel in the field of aviation security (AS) [6], the following features were selected:

- Legal and regulatory acts to ensure AS.
- Basic concepts, purpose and basics of AS.
- State of AS in civil aviation. Administrative and organizational aspects.
- Powers, roles and responsibilities of employees of AS systems. Organization of the company AS systems.
- Collateral management system AS. AS provisioning concepts.
- Providing AS for ground handling of aircraft.
- Organization of access and intra-facility modes.
- Airport configuration and secured restricted areas.
- AS measures within controlled and uncontrolled area. Control of access to aircraft.
- Technical means and equipment.
- Items and substances prohibited and (or) restricted for movement into the controlled area.
- Organization of screening of personnel, visitors and vehicles.
- Rules for conducting pre-flight and post-flight inspections.
- Inspection of passengers using technical means. Contact method of inspection.
- Inspection of baggage and hand luggage using an X-ray television security system (introscope).
- Surveillance and survey method (profiling).
- General information on terrorism and acts of unlawful interference. General information about explosive devices, explosives, weapons and ammunition. Detection, identification, concealment.
- Threats in the activities of civil aviation. Characteristics of offenders. Psychology of behavior of violators.
- Features of crisis situations. Determining the severity of an incident.
- Procedure for the AS system in non-standard situations.
- Anti-intrusion program.
- Aircraft protection and protection measures on the ground. The procedure for inspecting aircraft on the ground.
- Control over the implementation of technological processes to ensure AS.
- Crisis management. Conflict resolution skills.
- Methods for conducting audits and inspections.
- AS standards, rules and procedures.

The results analysis of inspections of the leading international airports of the Russian Federation made it possible to obtain 416 training examples.

The next stage in the formation of the training sample is the transformation of features, including:
- processing of anomalous values, contradictions and duplicates;
• restoration of missing values;
• data transformation.

In our case, the initial data presents the result of expert assessments of specialists compliance. The set of checks is fixed. Expert judgment can range from 0 to 9. Therefore, there are no abnormal values, contradictions, duplicates and missing values in the training set.

Data transformation consists of data encoding and scaling - bringing to a certain range. Neural networks work only with numbers, since their work is based on arithmetic operations of a weighted sum. Therefore, all input and output data of the neural network must be encoded as numbers. Our dataset contains traits in the form of numbers that do not need to be encoded, and binary targets: pass and fail. Let's encode the value "good" with one, and "bad" - with zero. We use minmax scaling (min max scaling), or normalization (normalization) [7]. In MATLAB, normalization is done automatically.

3. Research of a neural network in MATLAB
The neural network was preliminarily investigated in MATLAB using the Neural Network Pattern Recognition App visual programming tool of the Deep Learning Toolbox of the MATLAB system [6].

The following network structure was experimentally selected: input layer - 26 input features, hidden layer - 10 neurons, output layer - 1 neuron. In the hidden layer, the hyperbolic tangent is used as the activation function, in the output layer, the softmax function [7], that is, the network output represents the probability of assigning the checked employee to the "good" class.

MATLAB uses cross entropy as a loss function for classification problems. The network is trained using the Scaled Conjugate Gradient method. To prevent overfitting, cross-validation with early stopping was used hold-out cross-validation [9]. With this approach, the original training set was randomly divided into three subsets:
• Training Set, which is used to adjust the weights of the network (60% of the total number of training examples);
• Test Set, which is used to check the quality of training (10%);
• Validation Set, which is used throughout the training to detect the phenomenon of overfitting (30%).

The study stops when the loss function on the Validation Set stops decreasing.

The network training results are shown in confusion matrices (figure 1).

Figure 1. Confusion matrices.
In our problem, "true" (output class is 1) are employees who meet the requirements. "False" (output class is 0) — employees who do not meet the requirements. The confusion matrices show the number of classification outcomes: $N_{TN}$ — the number of truly negative outcomes (the actual class of the example is 0 and the model will return 0); $N_{TP}$ — the number of false positive outcomes (the example class is 0, and the model for it will generate output 1); $N_{FN}$ — the number of false negative outcomes (the target variable takes the value 1, and the model will give 0 at the output); $N_{FP}$ — the number of truly positive outcomes (the actual class of this example is 1 and the model outputs 1).

The confusion matrices show the estimates of accuracy — the number of correctly classified observations, referred to the total number of observations

$$R_{AC} = \frac{(N_{TP} + N_{TN})}{(N_{TP} + N_{TN} + N_{FP} + N_{FN})}.$$  

Confusion matrices show the high quality of the classification. On validation set, employees who do not meet the requirements (class 0) are identified with an accuracy of 100%. Eligible employees (class 1) are identified with an accuracy of 97.4%.

Let's calculate the main indicators of the quality of the neural network classifier [10] using the confusion matrix (figure 1). The calculation will be carried out using validation set. From the confusion matrix (figure 1) we get: $N_{TP} = 76$; $N_{FP} = 0$; $N_{TN} = 47$; $N_{FN} = 2$. Since the training sample is not balanced (the number of examples with different outcomes is significantly different), then to assess the accuracy, we use precision, i.e. the accuracy of predicting a positive outcome (employees who meet the requirements):

$$R_{PP} = \frac{N_{TP}}{(N_{TP} + N_{FP})} = 1.00.$$  

Recall, or Sensitivity, that is, the proportion of truly positive examples is 97.4% — of all employees identified as satisfying:

$$S_k = \frac{N_{TP}}{(N_{TP} + N_{FN})} = 0.974.$$  

Specificity, i.e. the proportion of correctly classified unsatisfactory employees is 95.9%:

$$S_p = \frac{N_{TN}}{(N_{TN} + N_{FP})} = 0.959.$$  

Thus, the developed neural network classifier provides a high-quality classification.

4. Program for neural network assessment of personnel readiness
The MATLAB Deep Learning Toolbox is convenient for building and researching a neural network using a variety of training examples, but it does not allow assessing the level of readiness of an individual employee. In MATLAB, you can save the parameters of the trained network. Another MATLAB program, having loaded the network parameters and received the employee's data, can evaluate his readiness. However, this approach is impractical for a number of reasons: it will require the purchase of expensive licenses for each workplace; a MATLAB program will require special user skills to work with the MATLAB system; the program will make rather high demands on the hardware and software platform.

An alternative approach is the development of a standalone program in C ++, which will: ensure low cost of the program; get an executable file that can be run on Windows computers of various configurations; use a graphical interface familiar to the user, which minimizes the requirements for users. When developing an autonomous program, it is advisable to use the structure and parameters of the neural network selected in MATLAB.

The developed Neurotest program for assessing the readiness of an aviation security specialist to perform professional tasks provides:
• entering the personal data of the specialist and the points awarded to him for each requirement of the competence;
• formation of the final assessment of the specialist's readiness;
• automatic saving of information on the results of the specialist's assessment in the database;
• viewing the saved results of personnel assessment.

After launching the Neurotest program, the main application window will appear on the screen, which is shown in figure 2. The main menu contains four items: the "Test" item is intended to enter the initial data and start the assessment procedure; the "Results" item is intended to view the results of completed and previous assessments; the "Help" item is intended to display information about the program; the "Exit" item exits the program.

To determine the assessment of the specialist's readiness, select the "Test" menu item, after which a dialog box for entering the specialist's personal data will appear (figure 3).

When entering personal data, validation is applied, according to which the first letters of the surname and first name must be uppercase, the remaining letters must be lowercase. The size of the input field is 20 symbols. You can move between input fields using the cursor keys "↑" and "↓" and the "Tab" key. You can also select a field for input or editing using the mouse. After filling in all the input fields, the "Ok" button becomes active, and after clicking on it, the current window will close and a dialog box will appear for scoring at the request of the competencies. In the window for entering points, all points must be entered, and only numbers from 0 to 9 can be entered.
After clicking on the "Ok" button (it is active after entering all the points), the dialog box will close and the entered array of points will be used to calculate the final assessment of the readiness of an aviation security specialist to perform professional tasks. The result of the specialist's check in the form of a "good" or "bad" grade assigned to him is displayed on the screen using the information window, which is shown in figure 4.

![Information window](image)

**Figure 4. Information window.**

After the evaluation is displayed on the screen, information about the specialist (last name, first name, awarded points, final grade, as well as the date and time of the assessment) is automatically saved in the database. When you select the "Results" menu item, a dialog box will appear in which the results of previously conducted competency tests are displayed.

5. Conclusion

The presented neural network solves the unique task of classifying aviation personnel. The specificity of the requirements for personnel leads to a noticeable uncertainty and ambiguity of the test results in the certification process, which are very difficult to overcome, which significantly complicates the process of making decisions about the readiness of a specialist for production activities. Due to the fact that a non-algorithmic analysis of the initial data is implemented in the network, it is possible to include informal, intuitive representations of the certification expert about personnel in the decision procedure through the implementation of special network training.

The proposed version of the neural network is quite well adapted to the conditions of use in modern automated security systems based on information management.

The transition in the aviation security management system to a competency-based methodology for assessing the level of professional readiness of personnel significantly increases the quality of the facility protection system.

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