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THE ARTIFICIAL INTELLIGENCE METHODS APPLICATION FOR ENEMY'S GROUP TARGET OBJECTIVES CLUSTERIZATION AND CLASSIFICATION

Abstract. *The article shows that artificial intelligence methods, namely neural networks, can be used to solve the problems of clustering and classification of enemy group targets.*

To solve the problem of clustering enemy group targets, a neural network of the SELFORGMAP type (self-organized maps) may be chosen, which consists of a layer of neurons and can classify a data set of vectors with any dimension. As revealed by the analysis of training the neural network for clustering enemy group targets, the NN SOM GTs has the best accuracy with 5 neurons in the hidden layer. The clustering of enemy group targets showed that they can be divided into 5 clusters.

The convolutional neural network such as the CNN GTs may ivebe chosen to classify enemy group targets. The training of the CNN GTs was carried out using the Levenberg – Marquardt algorithm. Based on the training results, the neural network for classifying group target objects was trained, verified and tested with an accuracy of 100%, the overall accuracy of the neural network for classifying enemy group target objects was 100%. The results of analyzing the histogram of errors between the target values and the predicted values after training the neural network for classifying group targets show that the error value is 0.00022. Since the errors are close to zero, the trained neural network performs well in classifying group targets. Testing the performance of the CNN GTs on an arbitrary set of group target objects showed 100% coincidence of the classes of actual group target objectives obtained using the CNN GTs.

The direction for further research could be the creation of neural networks to solve the problem of distributing a heterogeneous swarm of striking unmanned aerial vehicles over the objectives of an unsteady heterogeneous group target.

Keywords: *clustering, classification, neural network, artificial intelligence, group target, unmanned aerial vehicles, swarm, russian-Ukrainian war.*

Introduction

Statement of the problem. During the russian-Ukrainian war, changes are taking place in the strategy, forms, and methods of employing troops. One of the reasons for this is the development of unmanned systems, the use of which has become widespread and allows the performance of a wide range of tasks.

At present, the use of unmanned systems is an effective means of destruction in both positional and maneuver defense. At the same time, at the tactical level, the current tasks are to destroy non-stationary group targets of the enemy both on the front line and in depth; to deliver massive sudden strikes on objectives of its critical infrastructure and important communications. The use of other strike means and electronic suppression tools, which are expensive to operate and produce, is minimized.

Currently, the capabilities of unmanned systems are increasing due to the use of swarms of attack UAVs, which significantly affects the course of combat operations [1].

Both homogeneous and heterogeneous swarms of strike UAVs may be used. In this case, from the point of view of organizing swarm control, swarms should consist of strike UAVs of the same type (either quadcopter-type UAVs or aircraft-type UAVs) [1].

Homogeneous swarms of strike UAVs consist of identical strike UAVs, while heterogeneous swarms consist of UAVs of different classes.

Since a group target almost always consists of heterogeneous objects, a heterogeneous swarm of strike UAVs must be used to destroy such a target.

To defeat a heterogeneous group target with a heterogeneous swarm of strike UAVs with maximum efficiency, it is necessary to solve the optimization problem of distributing heterogeneous strike UAVs among the objectives of the heterogeneous group target.

To solve the specified optimization problem, it is necessary that the UAV target assignment system for group target objectives classify group target objectives and assign each object a strike UAV or several strike UAVs of the corresponding class.

Artificial intelligence methods and algorithms, namely neural networks (NNs), may be used to classify group target objects [2, 3].

Analysis of recent research and publications. Given the promising nature of artificial intelligence technologies [2–4], the development of neural networks for clustering and classification of group target objectives is a relevant task.

In particular, in the work [5], a neural network was used to develop a system capable of learning to recognize the type of UAV based on the results of the analysis of traffic transmitted by it to the ground control station. The author noted that the ability of a neural network to generalize, with a sufficient volume of the training sample, allows the NN to extrapolate its knowledge about known types of network actions to unknown types. In this case, the choice of an NN architecture adequate to the tasks plays a decisive role.

In [6, 7], the application of different types of neural networks for object recognition and classification is considered.

In [8, 9], clustering and classification of attack UAVs were carried out based on neural networks. The results of the analysis of the dependence of clustering accuracy on the number of neurons in the hidden layer showed that the neural network for clustering attack unmanned aerial vehicles NN SOM FPV UAVs has the best accuracy with 18 neurons in the hidden layer. Clustering of attack unmanned aerial vehicles demonstrated that they can be divided into 4 clusters. At the same time, they can be grouped into 3 classes according to the number of UAVs in each cluster. Training of the CNN FPV UAVs was carried out using the Levenberg-Marquardt algorithm, the overall accuracy of the neural network for classifying attack unmanned aerial vehicles was 98.9%.

In general, an analysis of scientific publications indicates that the development of objectives classification technologies based on neural networks has significant prospects, especially in the context of increasing accuracy, operation speed, and resistance to rapidly changing conditions.

The issues of clustering and classification of group target objects based on neural networks have not received enough attention. Therefore, clustering and classification of group targets, on the one hand, and certain classes of strike UAVs, on the other hand, deserve special attention.

Purpose of the article – development of neural networks for clustering and classifying enemy group target objectives based on artificial intelligence algorithms.

Presentation of the main material

In [10], it is proposed to use the following classification of types of objects (targets) located in the terrestrial (surface) and air regions of the Earth's space:

a) the first type – point objects (samples of ground (surface) equipment, people, small groups of people);

b) the second type – linear objects (vehicle columns, automobile and railway, oil and gas pipelines, power lines);

c) the third type – flat objects (large groups of point objects, agricultural fields, forest areas, settlements, flood and earthquake zones);

d) the fourth type – spatial objects (areas of chemical and radioactive contamination of the air basin).

In addition, group target objects can be classified by strike means groups (Table 1).

Table 1

Groups of strike objects

Strike tools group number	Object group name	Strike objectives
1st group	Tactical-level strike tools, strike reconnaissance complex, tactical SS	Tactical SS missiles launcher platoons, artillery platoons (batteries), MLRS platoons (batteries), mortar companies
2nd group	Troop and weapons command and control bodies	CP (FCP, MCP) FA, AC, divisions, brigades, battalions, TCCB, TCCC, reconnaissance and electronic warfare equipment
3rd group	Aviation grouping facilities	Tactical aviation at airfields, army aviation at landing pads
4th group	Air defense facilities	Batteries (platoons) of SAMs
5th group	Troop engroupments	Motorized infantry, infantry, tank, mortar companies, anti-tank destroyer companies in areas of concentration, on the march, during advance and deployment
6th group	Other objects	Rear facilities, infrastructure, etc.

Therefore, we have a fairly large number of diverse (by nature) objects in the enemy's operational structure, which emphasizes the need for a balanced approach to the rational distribution of strike UAVs among group target objects, taking into account their priority.

Let's consider how the mission of clustering and group-target objects classifying may be solved using neural networks.

The creation and use of neural networks for the classification of group target objects involves [8] (Fig. 1): 1) formation of a database of group target objects; 2) selection of neural network architecture; 3) selection of a neural network training algorithm; 4) training of a neural network; 5) evaluation of the neural network training results; 6) use of a neural network for the classification of group target objects.

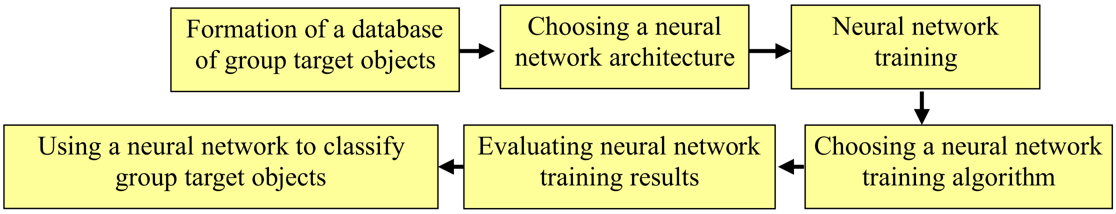

Fig. 1. Stages of creating and using a neural network for classification group target objects

1. Formation of a database of group target objects. The database of group target objects was formed from various types of weapons and military equipment (WME): tanks, multiple launch rocket systems, artillery systems of 100 mm caliber and larger, mortars, anti-tank missile systems, air defense systems, aircraft, cars, anti-ship weapons, warships, enemy UAVs (Table 2).

Table 2

Number of samples of group target objects by type of weapons and military equipment

No. salary	Types of weapons and military equipment	Number
1.	Tanks	50
2.	IFVs	27
3.	APCs	27
4.	AFVs	18
5.	Launchers for tactical and operational-tactical SS missiles	5
6.	Multiple launch rocket systems	9
7.	Artillery systems of 100 mm caliber and larger	22
8.	Mortars	27
9.	Anti-tank weapons (artillery)	5
10.	Anti-tank missile systems	21
11.	Air defense systems	81
12.	Aircraft	73
13.	Helicopters	20
14.	Cars	20
15.	Anti-ship weapons	5
16.	Warships	26
17.	Unmanned aerial vehicles	17
18.	Personnel (group, department, etc.)	5
	Total number of samples:	456

Table 2 lists 456 samples of various types of weapons and military equipment (WME) used by the enemy in the russian-Ukrainian war.

The enemy group target objects presented in Table 1 may be grouped by classes.

2. Choosing the architecture of the neural network for clustering group target objects. In order to distribute the group target objects by classes, we will apply the clustering procedure. In the clustering task, the neural network will group the group target objects into clusters according to the combat potential of the WME sample.

To cluster objects of a group target using a neural network, it is necessary to create and train the network, as well as evaluate its effectiveness using various visualization tools (the Clustering application in the MATLAB application package).

For clustering of group target objects, we will choose a neural network of the SELFORGMAP type (self-organizing maps), which consists of a layer of neurons that can classify a data set of vectors with any dimension into as many classes as the layer has neurons. The neurons are arranged in a two-dimensional topology, which allows the layer to form a representation of the distribution and a two-dimensional approximation of the topology of the data set. We will train the network using the batch algorithm self-organizing map (SOM).

Self-organizing maps learn to cluster data based on similarity, topology, with the advantage of assigning the same number of instances to each class.

3. Clustering of group target objects. For clustering of group target objects, a matrix with input data of size 1x456 was formed (Table 2).

It has been experimentally established that a self-organized map should consist of 5 neurons, and the neural network should have one input and one output.

The architecture of the neural network for clustering group target objects is shown in Fig. 2.

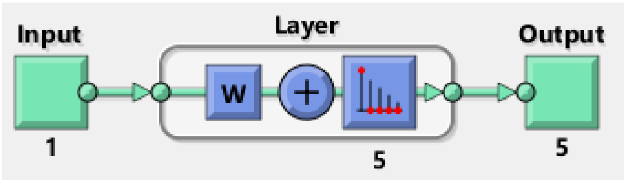

Fig. 2. Architecture of a neural network for clustering group target objects (NN SOM GTs)

NN SOM GTs supports the hextop topology, which creates a set of neurons arranged in a hexagonal order (Fig. 3).

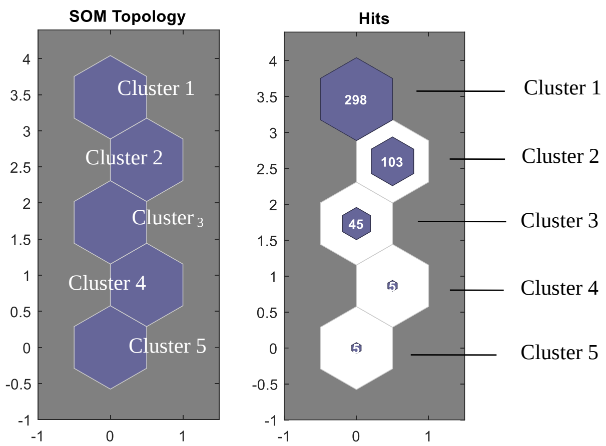

Fig. 3. Cluster diagrams for group target objects: a) by clusters and b) by number group target objects

The results of data analysis on group goal objects (Table 1) using the SELFORGMAP neural network of group goal objects (NN SOM GTs) are shown in Fig. 3 and Fig. 4.

Therefore, cluster 1 includes 298 group target objects, cluster 2 includes 103, cluster 3 includes 45, cluster 4 includes 5, and cluster 5 includes 5 objects.

The results of the distribution of group target objects into clusters are presented in Table 2.

In the future, this will allow using the created neural network for clustering group target objects (NN SOM GTs) for their distribution into classes.

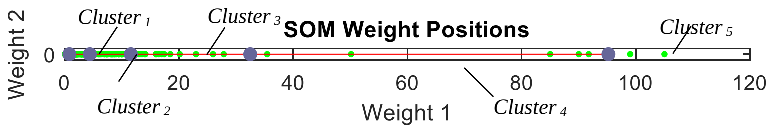

Fig. 4. Distribution of group target objects by clusters

Fig. 4 shows the distribution of group target objects across clusters as green dots, which show how NN SOM GTs classifies group target objects.

Therefore, clustering of enemy group target objects made it possible to divide them into classes.

5 classes of enemy group target objects were identified:

Class 1 includes group target objects that have a combat potential of 0.6-2.7;

to the 2nd class – group target objects with a combat potential in the range from 2.7 to 8;

up to the 3rd class – group target objects with combat potential in the range from 8 to 23;

up to the 4th class – group target objects that have a combat potential in the range from 23 to 90;

up to the 5th class – group target objects that have a combat potential of over 90.

4. Choosing a neural network architecture for classifying group target objects. The neural network for classifying group target objects based on the values of their combat potentials was developed in the MATLAB application package.

Data preparation. Data for the problem of classifying objects of group goals is configured for the neural network by organizing the data into two matrices: the input matrix X(p) and the target matrix T(y).

The study used the characteristics of more than 456 samples of enemy group target objects.

The neural network for classifying group target objects has two layers of neurons: hidden and output (Fig. 5).

It has been experimentally established that the best classification result is achieved if the number of neurons in the hidden layer is 15 neurons.

The connection between neurons in the hidden layer is carried out using the tansig function, and in the output layer – using the lin function [9].

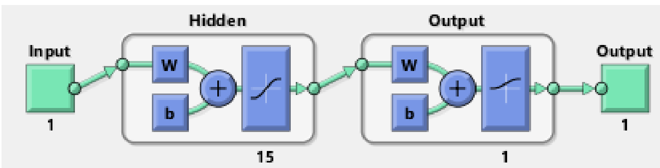

Fig. 5. Architecture of a neural network for group targets object classification (CNN GTs)

Let's divide the database of group goal objects into training, validation, and testing sets.

The training set is used to train the neural network. Training continues as long as the network continues to improve the validation set. Training a neural network can be viewed as solving an optimization problem. Its goal is to minimize the error function on this sample by choosing the values of the weights W. The function trainbr is chosen as the training function for the neural network for classifying objects of group goals.

The trainbr function is Bayesian backpropagation regularization. It is a network training function that updates the weights and biases according to Levenberg–Marquardt optimization, which minimizes the combination of squared errors, weights, and biases, and then determines the correct combination to produce a network that generalizes well. This process is called Bayesian regularization.

Training occurs according to the trainbr training parameters. These parameters in the Matlab programming environment are:

net.trainParam.epochs – maximum number of epochs for training (default value – 1000);
net.trainParam.show – epochs between displays (NaN if there are no displays) – 25;
net.trainParam.showCommandLine – create command line output (default value – false);
net.trainParam.showWindow – show the training graphical interface (default value – true);
net.trainParam.mu – Marquardt adjustment parameter (default value 0.005);
net.trainParam.mu_dec – reduction factor for mu (default value is 0.1);
net.trainParam.mu_inc – increase factor for mu (default value – 10);
net.trainParam.mu_max – maximum value for mu (default value – 1e10);
net.trainParam.max_fail – maximum number of validation errors (default value – 0);
net.trainParam.min_grad – minimum performance gradient (default value is 1e-7);
net.trainParam.time – maximum training time in seconds (default value – inf).

Each weight and bias are updated according to their learning function after each epoch (one pass through the entire set of input vectors).

The test set provides a completely independent assessment of the accuracy of the neural network's classification of group target objects.

So, we generate data, create and train a neural network, and evaluate its performance using mean square error and regression analysis.

Of the 456 group goal objects, their distribution is as follows: 319 (70%) – training; 69 – verification; 68 – testing.

The neural network was trained using the Levenberg–Marquardt algorithm [5].

Fig. 6 shows the error matrix during training, validation and testing of the neural network for classifying group target objects.

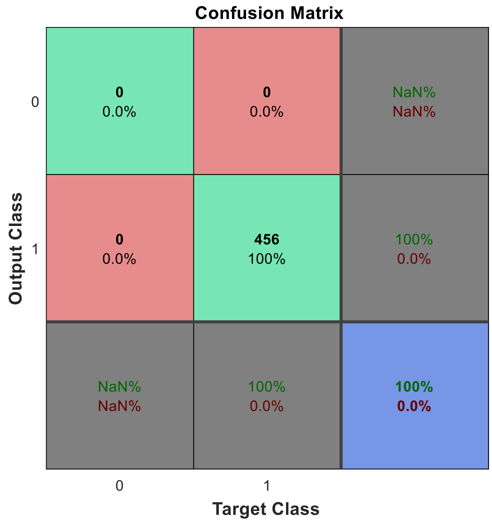

Fig. 6. Error matrices during training, validation and testing of a neural network for group target objects classifying

Fig. 6 shows that the neural network for classifying group target objects was trained, validated, and tested with accuracies of 100%, and the overall accuracy of the neural network for classifying group target objects is 100%.

When solving an optimization problem, the first derivatives of the objective and nonlinear constraint functions are calculated, and the function check Gradients is used to check the programmed derivatives. In addition, it is checked whether the gradient is calculated correctly near the random starting point [11–12].

Fig. 7 shows the results of estimating the gradient of the objective function.

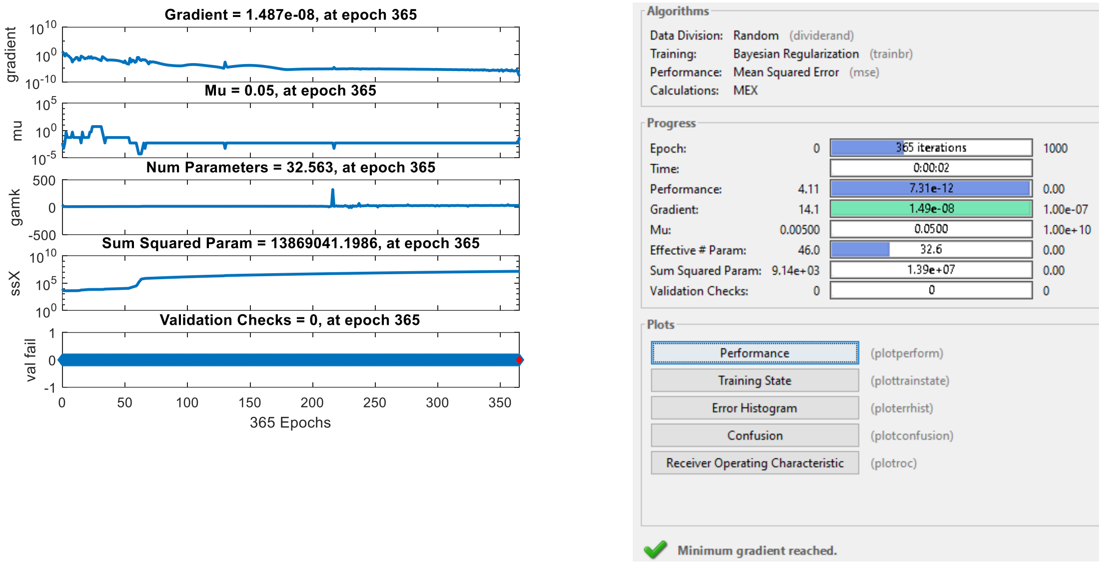

Fig. 7. a) Checking the validity of gradients; b) Checking the performance of training CCN GTs

Fig. 7 shows that the best learning performance of CCN GTs is achieved at the 365th epoch.

Fig. 8 shows a histogram of the errors between the target values and the predicted values after training the neural network for classifying objects of group targets. The histogram shows that the GTs CNN has an error with an accuracy of up to the fifth sign.

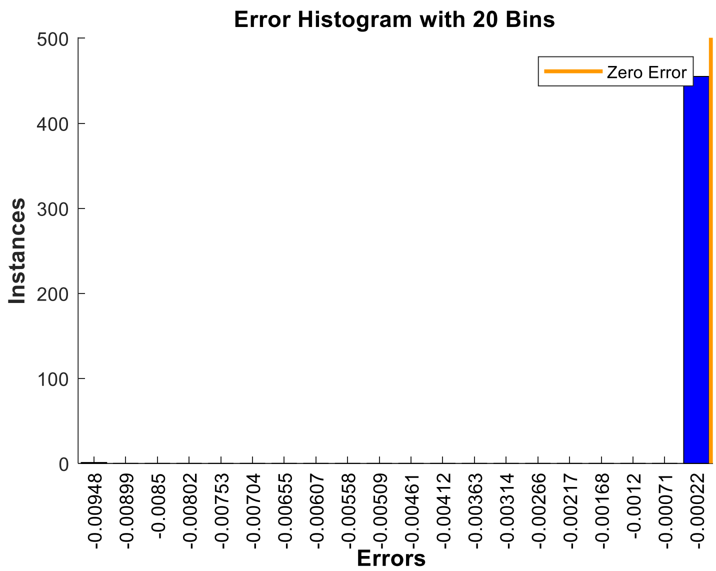

Fig. 8. Error histogram

The error value of 0.00022 indicates the best performance of the network. Since the errors are close to zero, the neural network models the object classification of group goals well.

Fig. 9 shows a graph representing the training, validation, and testing data of a neural network for classifying group target objects.

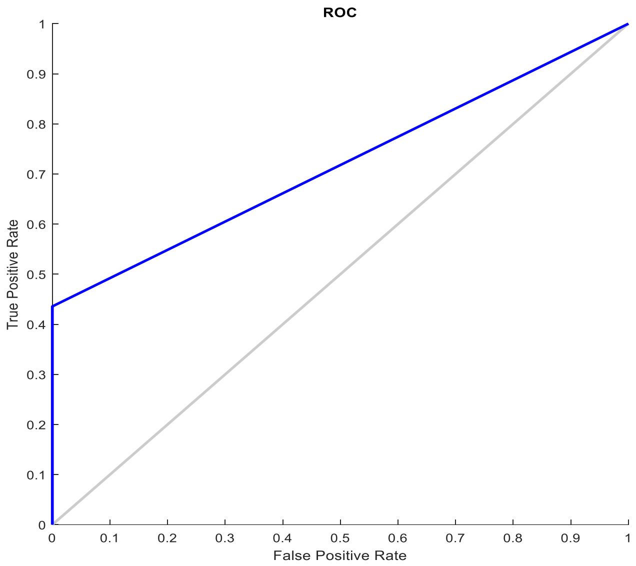

Fig. 9. Training, validation and testing data for a neural network classification group target objects

The dotted line on the graph represents the optimal outcome, and the solid line is the linear regression line that best fits the outcomes and targets.

The graph of the change in the value of the objective function over epochs – learning cycles is shown in Fig. 10.

Among the training parameters are set:

goal – the maximum allowable value of the objective function;

epochs – the maximum allowable number of network training cycles;

show – the step of displaying information about network training on the screen, set in training cycles.

The graph indicates the iteration at which the verification efficiency reached a minimum [11–12].

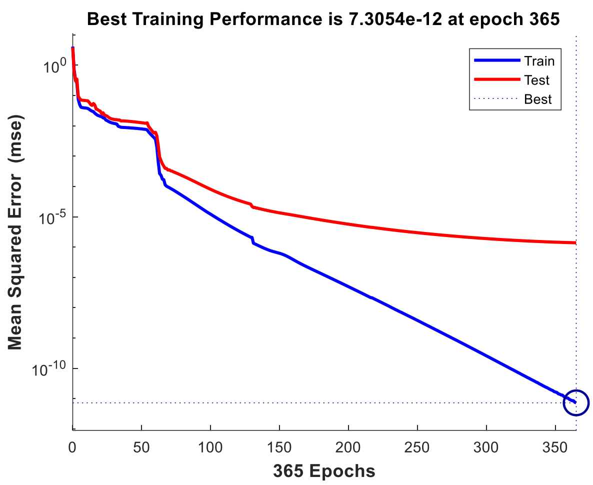

Fig. 10. Graph of the change in the value of the objective function during the learning process

Fig. 10 shows that at the 365th iteration, a local minimum of the objective function was reached.

Therefore, a convolutional neural network for classifying group targets (CNN GTs) can be used to classify group target objects with different combat potential values.

To test the operation of the CNN GTs, an arbitrary set of group target objects with combat potential values was taken, which are given in Table 3.

The results of the work of the CNN GTs are presented in the fourth row of Table 3.

Table 3

Results of the work of CNN GTs

No. salary	Objects group goals	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Combat potential	91.74	50.15	35.46	27.85	25.98	23.00	20.15	18.50	17.43	17.00	16.50	16.00	16.00	14.14	14.00	2.93
2	Class (actual)	5	4	4	4	4	4	3	3	3	3	3	3	3	3	3	2
3	Class (neural network)	5	4	4	4	4	4	3	3	3	3	3	3	3	3	3	2
4	Coincidence	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
No. salary	Group goal objects	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	Combat potential	2.90	2.89	2.88	2.86	2.86	2.74	2.73	2.70	2.58	2.57	2.47	2.46	2.45	2.37	2.30	2.30
2	Class (actual)	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1
3	Class (neural network)	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1
4	Coincidence	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

The results of the analysis of actual data and data obtained using CNN GTs show 100% coincidence of object classes of group targets.

Therefore, a convolutional neural network for group target object classification (CNN GTs) can be applied to classify enemy group target objects with different combat potential values.

Conclusions

For the classification of enemy group target objects, a convolutional neural network of the type CNN GTs may be selected. Training CNN GTs using the Levenberg-Marquardt algorithm showed good results. According to the training results, a neural network for classifying group target objects was trained, verified and tested.

The overall accuracy of the neural network for classifying group target objects was 100%.

The results of the analysis of the histogram of errors between target values and predicted values after training the neural network for classifying group target objects indicate that the error value is 0.00022.

Since the errors are close to zero, the trained neural network performs the classification of group target objects well.

Testing the performance of CNN GTs on an arbitrary set of group target objects showed 100% coincidence of classes of actual group target objects obtained using CNN GTs.

The direction of further research may be the creation of neural networks to solve the problem of distributing a heterogeneous swarm of strike unmanned aerial vehicles over objects of a non-stationary heterogeneous group target.

References

1. Shovkoshytny I.I., Vasylenko O.A. Development of a logical-temporal model of swarm use of strike unmanned aerial vehicles taking into account typical methods of their group use in modern conditions. *Collection of scientific papers of the Center for Military-Strategic Research of the National Defense University of Ukraine*. 2024. No. 3 (83). Pp. 108–116.
2. Nikitina L.O., Nikitin S.O. Models and methods of artificial intelligence in computer games. Kharkiv: “Madrid Printing House”, 2018. 102 p.
3. Methods and systems of artificial intelligence: tutorial / edited by D. V. Lubko, S. V. Sharov. Melitopol: FOP Odnorog T. V., 2019. 264 p.

4. Artificial Intelligence and Neural Networks. 12 Books in One to Help You Bring Innovation to Life. Kharkiv: Monolit Bizz LLC, 2024. 216 p.
5. Ivashchenko A. Information and software support for the identification system of unmanned aerial vehicles. Sumy: Sumy State University, 2022. URL: chrome-extension://efaidnbmnnnibpcajpcglclefind-mkaj/https://essuir.sumdu.edu.ua/bitstream-download/123456789/88897/1/ Ivashchenko_bac_rob.pdf.
6. Oganezov A. L. Application of neural networks in pattern recognition tasks. Autoref. thesis ... candidate physics and mathematics Sciences: 05.13.11. Tbilisi. 2006. 20 p.
7. Perepelitsyn S.O. System of protection against UAV strike threats using neural network analysis blocks. *Science-intensive technologies.* 2020. No. 1 (45). DOI: 10.18372/2310-5461.45.14579.
8. Gusak Yu.A., Vasylenko O.A. Clustering and classification of strike unmanned aerial vehicles based on neural networks. *Air Power of Ukraine.* 2024. No. 1 (6). P. 141–152. DOI:10.33099/2786-7714-2024-1-6-141-152.
9. Gusak Yu. A., Vasylenko O. A. Algorithm for creating a neural network for classifying strike unmanned aerial vehicles. *Modern information technologies in the field of security and defense.* 2024. No. 2 (50). P. 54–68. DOI: 10.33099/2311-7249/2024-50-2-54-68.
10. Berezhny A. O. Methods and information technology of automated planning of flight routes of unmanned aerial vehicles to increase the efficiency of object search. Dissertation ... candidate of technical sciences. 05.13.06. Kharkiv: KhNUPS, 2020.
11. MATLAB Handbook: electronic tutorial on course and diploma design. Kyiv: NTUU “KPI”, 2013. 132 p.
12. Tereykovsky I. A., Bushuyev D. A., Tereykovska L. O. Artificial neural networks: basic principles. Kyiv: NTUU “KPI”, 2022. 123 p.