A PROCEDURE FOR ISAR OBJECTS RECOGNITION WITH NEURAL NETWORKS ALGORITHM

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Abstract: With the development of inverse synthetic theory and the development of effective methods for obtaining high-quality image images in Inverse Synthetic Aperture Radars (ISARs), new possibilities are provided to obtain images of high-resolution flying objects. The current task is to solve the problems related to the automatic recognition of these images and the need to create algorithms to ensure the practical realization and information provision ISARs working on this principle.

In the development of means for more efficient detection of the images obtained by observing different flying objects, it is necessary to perform optimizations at the stage of modeling of the reflected complex trajectory signal. To improve the recognition process and information analysis in this area, simulation experiments were performed to restore high-quality images. The objects to be recognized in these images should use models with a detailed 3D structure that are as close as possible to real-world aircraft.

Based on the results known, obtained in the simulation observation experiments and analytical procedures on a 2D and 3D geometry object, this work proposes to introduce geometry adjustments of the 2D model in order to achieve a higher degree of similarity to the predicted Real reflected signal. The analysis of this approach, based on experimental simulation results and the Z buffer algorithm, gives grounds for defining different shading zones for the radar signal at a different angle of the object relative to the ISAR system.

When implementing a recognition algorithm, the availability of a ready database with a large number of detailed flying object models, their characteristics, their structure features and other indicators is essential for the rapid solution of the particular task. With these recognition system requirements and the availability of many models, it is essential that the image obtained from the ISAR can be classified by the maximum number of benchmarks.

In this article, a neural network is selected in which neuronal learning in the individual layers is performed by a backward-propagation algorithm. This type of neural network has proven metrics for recognizing symbols, printed text, and solid images.

This article offers a neural network architecture for automatic recognition of Inverse Synthetic Aperture Radar objects represented in images with high level of additive noise. A full explanation of the procedures of two-layer neural network architecture creating and training is described. The neural network is depicted in MATLAB and SIMULINK environment.

Keywords: neural networks, etalon model, transfer function.

1. INTRODUCTION

For the classification systems of Inverse Synthetic Aperture Radars (ISAR) the neural networks technologies for better image reconstruction are proven to be successful [a]. An pportunity for improved information analysis in that area is suggested to be the development of better algorithms for recognition of the various flying objects.

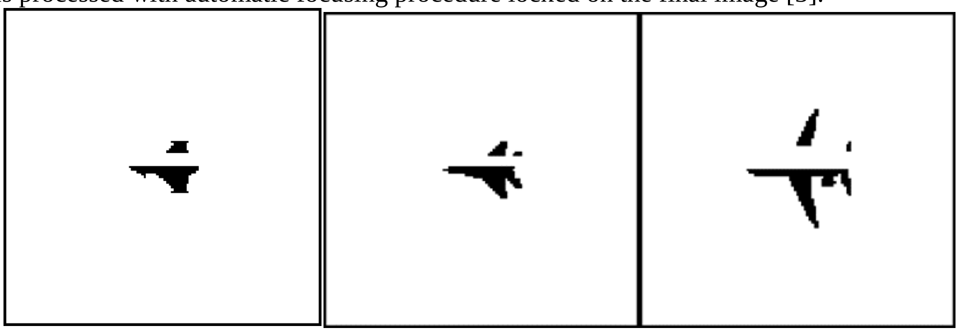
In [1] to solve the problem of recognition of not cooperating objects of observation, after acquiring radar image, an algorithm based on fuzzy logic can be used to make this classification with a high degree of credibility while controlling the error rate. The effect of uncertainty in the identification process is reduced if it can be trained or if the experience of expert can be studied [6]. Many opportunities are revealed for in-depth research and implementation of new ideas and approaches to accelerate the process of implementing the principles of inverse aperture synthesis in practice. At this stage a common standard for assessing the quality of the radar image is not created [4]. New methods for detecting and analyzing specific characteristics of objects in ISAR - images of moving objects [2] are needed in order to differentiate them into different classes. An algorithm for recognition of objects in the radar image by comparison with standard solid models of planes is presented in this paper.

2. PRECONDITIONS

One of the preconditions of the ISAR object classification procedure is that a database of standard 2D models of planes is developed. Sixteen aircraft models in a rectangular grid 128x128 pixels with dimensions of the network $\Delta X = \Delta Y = 0{,}5m$ are defined. Sixteen exemplary graphical-described solid models of the contemporary aircrafts

Eurofighter Typhoon, Pilatus 9M, Rafale, Mirage 2000, MiG-29, Gripen, Falcon 2000, F-22, F-18, F-16, C-130 H, Bombardier Q400, Boeing-747, Boeing-737, Boeing-707 and Embraer Legacy 600 are used for the experiments.

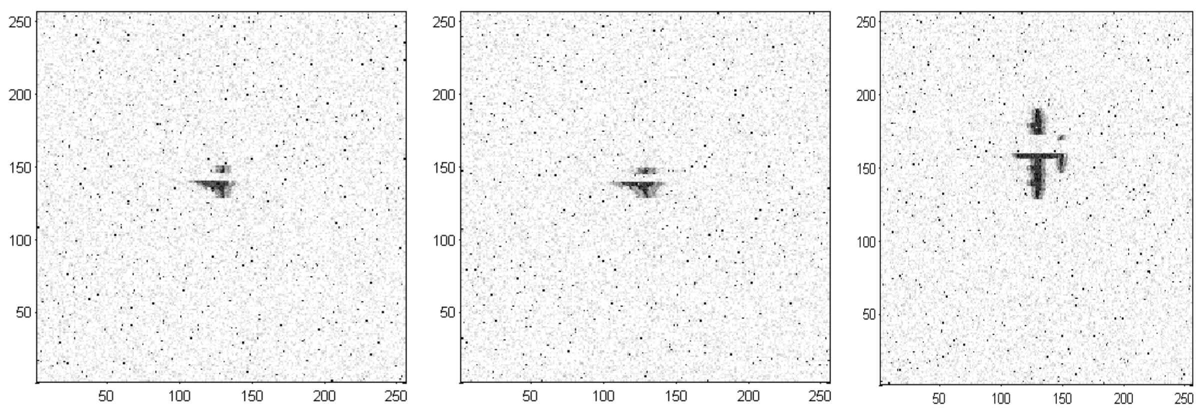
The etalon models are created based on detailed graphics, accompanied by accurate data on the geometric dimensions of the objects in three dimensions. Graphics cards and data are published in the web-site of FAS (Federation of American Scientists). Improved modeling and information analysis of ISAR systems are developed by implementation of detail 3D model of observed flying object [5]. It is assumed that the positions of some of the scatterers of the three-dimensional variations of the reference patterns are located with shading effect generation on other scatterers arranged behind them in the course of irradiation with the emitted radar signal. The effect of shading is shown in fig.1 as missing details of the structure of two-dimensional reference models. It is presumed that the ISAR image is processed with automatic focusing procedure locked on the final image [3].



Eurofighter Typhoon MiG-29 Embraer Legacy 600

Fig.1 Reference models of aircraft with the added effect of shading applied to parts of the structure.

A model of reconstructed ISAR image of the flying object in 128x128 pixel grid is used for the experiment in presence of Gaussian white noise with constant zero mean and variance 0.01 and “salt and pepper” noise with density 0.015. The additive “white” noise and impulse interferences produced by the peak noise are presented on figure 2. The experiments are developed in MATLAB environment.



(a) (b) (c)

Fig. 2. Reconstructed images in presence of additive noise for the aircrafts Rafale (a), Eurofighter Typhoon (b), C-130 H (c).

3. AN ALGORITHM FOR OBJECT RECOGNITION PROCEDURE

The neural network chosen to solve a specific task in recognition of the observed object in images obtained in inverse synthetic aperture radar have to pass the following criteria: to own property associativity to ensure proper identification of the object in the presence of noise in the image; to provide mechanism of aggregation that strongly deformed objects will not be mistakenly associated with some pattern; to exists opportunity to add new reference models; the learning process is short; to be distinguished by fast response of calculation procedures; to be suitable for realization of this recognition algorithm.

The availability of a ready database with a large amount of detailed models of flying objects (their characteristics, features of their structure) is essential for rapid decision on the specific task.

A neural network of type "Backpropagation" is chosen for the algorithm described before.

The problem is solved in converting the input image into a vector that can be classified by the neural network, similar to one of the classes (models) in a database, formed previously. A number of 16 etalon models, with dimensions of 128x128 pixels, is chosen for the comparison. Patterns are represented by binary matrices whose elements are numerical expression of the graphic-described solid models of aircraft with a known geometry. It is considered in that procedure it is possible error within 2 pixels in eight directions. To remove the ambiguity of the subject in position, twenty-five supporting matrices are formed for each model by translation of the etalon model at distance of 2 pixels in eight directions on the center of the image. The etalon models database is formed by these 400 matrices (16x25).

In the next stage of the chosen designing approach, the etalon matrices with the values of pixel intensity are reshaped in vertices of 128x128=16384 element so each matrix is transformed to one column. These vertices are formed in one matrix of "training", called Training (16384x400). 400 is the number of objects in the database, multiplied by twenty-five items, which are subject to the procedure for recognition, a 16,384 is the number of pixels in an image. At this stage, a matrix for the "desired result" named "Target" is also constructed, necessary for the neural network process of training. The matrix has a dimension 16x400 - 16 rows of available sites classified by their solid silhouettes and 400 columns, because each etalon model is represented by twenty-five of his positions. The location of the non-zero element of each column corresponds to the number of class (line) with which the result of recognition is associated.

In accordance with the algorithm proposed before, a neuron architecture consisting of two layers is designed by means of the Matlab programming language (fig.3) and is modeled in Simulink environment (fig.4).

In theoretical aspect, the learning process of this type of neural networks has proven convergence and therefore in a sufficiently long period of self-training, the neuron's weights should be suitably adjusted to produce correct classification of the vectors from the training sample.

The first layer of the neural network is "hidden" and is composed of 16 neurons with a log-sigmoid transfer function. These neurons form subclasses, some of which the input vector is classified with. The internal structure of this layer is depicted on fig.5.

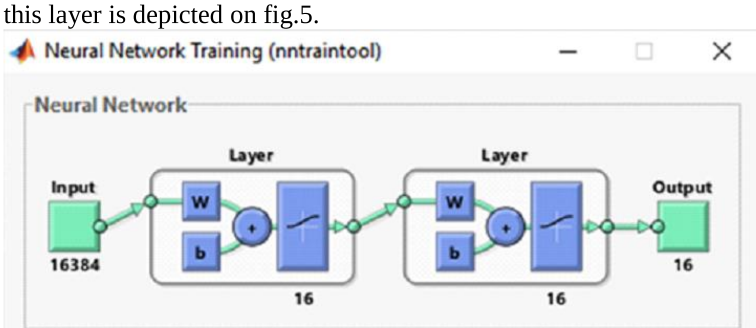


Fig.3. Block diagram of a neural network, designed in MATLAB environment.

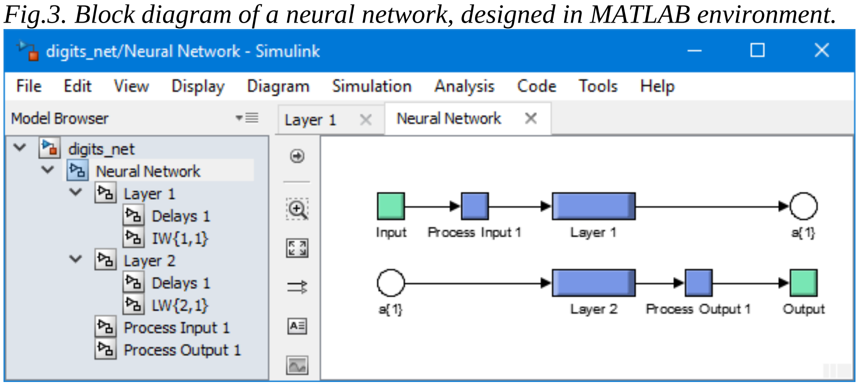


Fig.4. Scheme of the two-layer backpropagation neural network in Simulink.

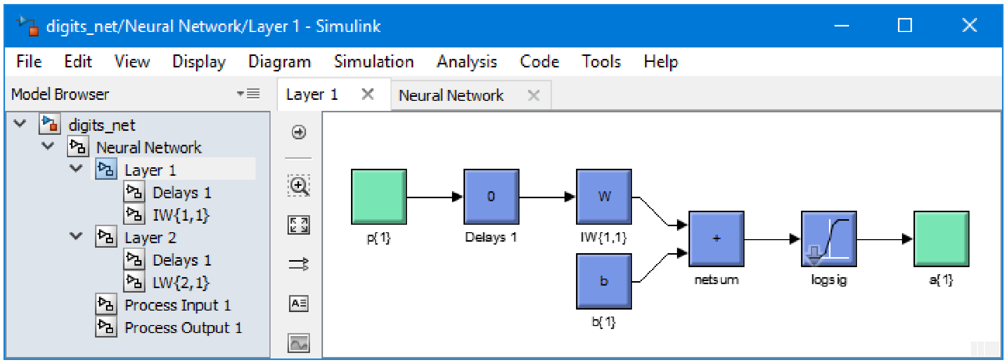


Fig.5. Structure of the first layer of the neural network built in Simulink.

A line called "Delays 1" that converts the elements of the input sequence into an input vector is in the layer structure. Log-sigmoidal transfer function provides a high sensitivity and high resolution in the recognition process.The weight matrix IW consists of sixteen weight vectors called "weights", whose specific values are determined in the education stage of neural network.

The second layer according to the final number of desired classes is designed to have 16 neurons. The number of the "winner" neuron is corresponding to that one of the all solid aircraft models to which the current input vector is brought to. The role of this layer is to process a classification of the first layer results and to generalize them to a fixed number of user classes (16). Its structure is similar to the structure of the first layer. The expanded structure of the inputs of the neurons in the layer is presented on figure 6, wherein the weight matrix LW is composed of sixteen weighting vector "weights", whose specific values are determined in the training stage of the neural network.

A training of the neural network is processed for the next stage of the neural architecture realization, which is essentially an adjustment of coefficients of the weighting matrices of neurons of the two layers. Embedded algorithms and procedures are used for automated self-training of the Matlab neural networks. A method for training a neural network with "teacher" in accordance with the following sequence of actions is processed. The initial training of the neural network is carried out free of interference.

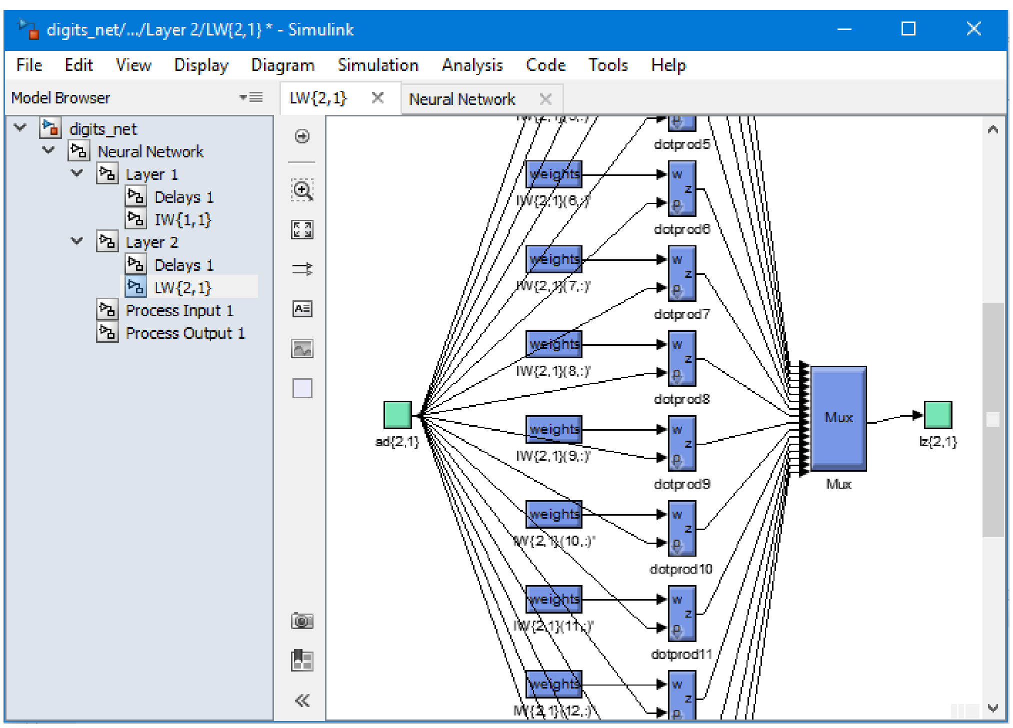
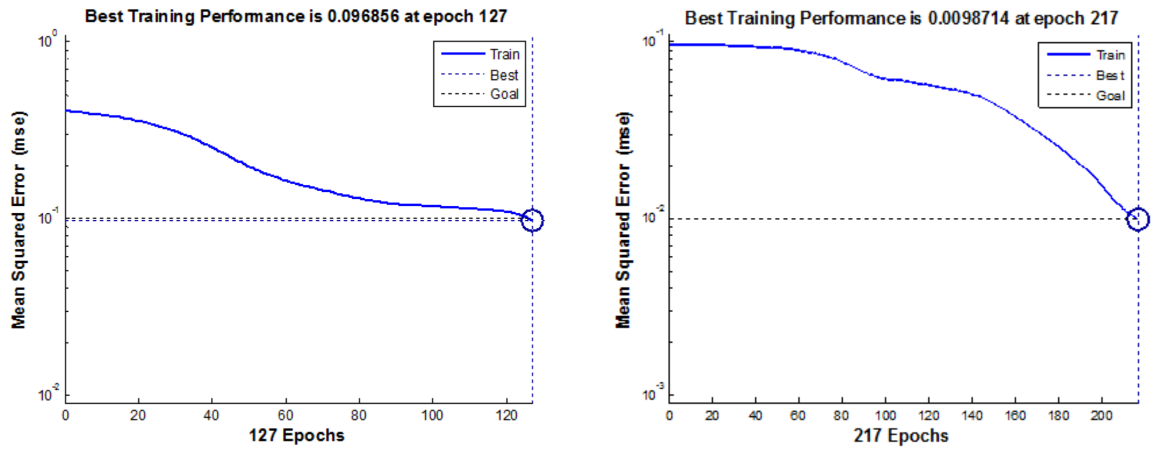


Fig.6. Structure of the weighting matrix at the entrance of the second layer of the neural network.

The input of the network is fed with "training" matrix Training1, containing the values of the intensities of the pixels obtained from the reference models. The desired result indicated by the matrix Target is the product the output of the network is designed to produce. Back propagation of error is the learning algorithm used. The goal for the possible error is chosen to be 0.1 and the error calculating function is of the type sse (sum squared error - accumulated value of the square error). The maximum of the training epochs is limited to 1000. The training results are illustrated on Figure 7 (a).



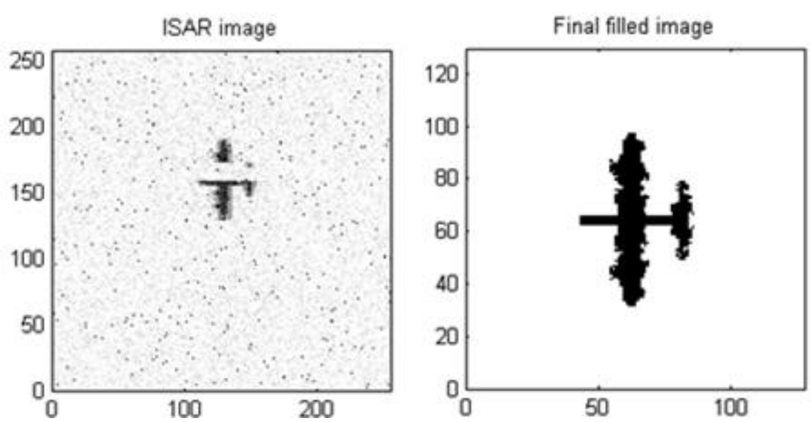
(a) (b)

Fig.7. Desired possible error 0.1 during the training in noise free environment is reached at 127 epochs – (a). Desired possible error 0.01 reached at 217 epochs – (b).

For the next step in The network training process higher requirements are implemented – the goal for the possible error is chosen to be ten times lower now - 0.01. The results of that training are shown on Figure 7 (b).

In line with the graphics on figure 10 and figure 11 the desired threshold is reached in two cycles of training in which the learning process is considered complete. Modeling the process of synthesis of this neural architecture is carried out in Matlab environment.

The results of the neural network for the ISAR observed object “C - 130 H” (fig.8) are presented on figure 9 where the position of the etalon model for that airplane is 11 and the object is properly classified.



(a) (b)

Fig. 8. ISAR image received (a) and optimized (b).

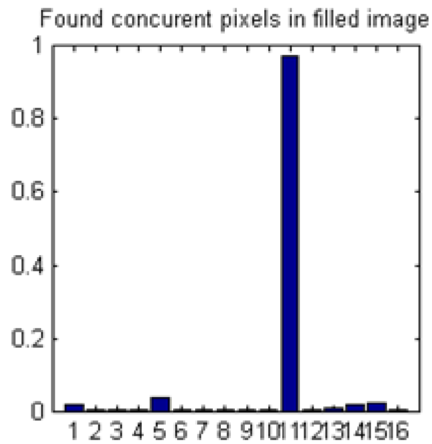


Fig.9 According to the neural network classification the object is recognized as the airplane C-130 H.

4. CONCLUSIONS

In this article neural networks algorithm for object recognition procedure in ISAR image is designed. As a result of the analysis and the carried out experiments the following conclusions can be made:

The chosen decision making algorithm is logical and accurate for the class belonging of the observed object.

The described neural network operates like an associative memory and makes correct classification of the ISAR objects in high level of noise environment as well as if the objects are not full or heavy damaged.

The used number of neurons in the first layer is smaller than in other networks because it depends of the chosen models in contrast to the image pixel number.

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