The paper deals with Radar Target Classification based on the use of a neural network. A radar signal was acquired from the output of a J frequency band non-coherent radar. We applied the three layer feed forward neural network using backpropagation learning algorithm. We defined classes of radar targets and designated each of them by its number. Our classification process resulted in number of a radar target class, which the radar target belongs to.

Keywords
classification of ground radar targets, neural network, radar signal processing

1. Introduction

Radar target classification is a process that results in a radar target class, which the radar target belongs to. In order to classify a radar target, a multilayer neural network can be used [1]. In our case, unknown radar targets are represented by a data vector of samples as follows

\[ x_k = [x_{k1}, x_{k2}, \ldots, x_{KN}] \]  

where \( N \) stands for the number of samples and \( k = 1, \ldots, K \) is the number of the observation period. Also we can define a data matrix \( X \) of its size of \( K \times N \), which consists of entries \( x_{kn} \), where \( n = 1, 2, \ldots, N \).

The classification process, which uses a neural network, consists of the two phases:

- The learning phase based on the use of signals of known radar targets
- The classification phase, in which unknown radar targets are classified into radar target classes.

A performance of both of them is described in the following part.

2. Classification Process

There are three steps of the classification process in each of the phases mentioned above:
- Preprocessing a radar signal
- Processing data by neural network
- Statistical evaluation of the processed data using a median filter.

The structure of the classification process is depicted on Fig. 1.

![Fig. 1 The structure of the classification process](image-url)

Preprocessing a radar signal includes a digitization of signal and generation of the vector \( x_k \).

In order to apply a neural network in radar target classification, a suitable neural network type, descriptors, and learning methods had to be chosen. During our experimentation we fully used the advantage of Neural Network Toolbox of Matlab.

2.1 Choice of neural network type and its descriptors

The choice of a suitable neural network is basically determined by:
- An input data form
- A capability of a used computing system
- Tasks that can be fulfilled by neural network, etc.
We experimentally investigated several structures of neural network. In our circumstances, according to experimental results, 3-layer feed forward neural network using a back-propagation learning algorithm (Fig. 3) was suitable to apply.

![Fig. 2 The topology of a neural network used for radar target classification](image)

The first layer called the input layer is fed by the radar target data vector \( x_k \), and consists of 30 neurons, \( i_1 \) to \( i_{30} \). Hidden layer consists of 100 neurons, \( h_1 \) to \( h_{100} \). The output layer consists of the single neuron, \( o_1 \), which gives the number of a radar target class, which the radar target was classified to. The neural network topology was chosen experimentally using experiences published in [2]. Along with the latter, a neural network was protected from over-learning.

### 2.2 Training set of known radar target signals

Let the vector of sample mean values of a known radar target signal be defined as follows

\[
e = [e_1, e_2, \ldots, e_N]
\]

where

\[
e_n = \frac{1}{K} \sum_{k=1}^{K} e_{kn}.
\]

The vector \( e \), acquired during a preprocessing phase, was used as a training set of known radar targets.

### 2.3 Learning of neural network

Learning of a neural network is a process of adaptation of a neural network parameters by means of stimulation according to the environment. To learn neural network, we used a learning algorithm, which minimized a mean square error (mse) defined later.

Let \( d(t) \) be assumed response of a neural network to the input vector \( e \) (in our case, it is the number of a radar target class) and \( u(t) \) is an actual response. Then the error signal is as follows

\[
err(t) = d_i(t) - u_i(t)
\]

The purpose of learning is to minimize the \( mse \) [2]

\[
J = E[\frac{1}{2} \sum_t err^2(t)]
\]

Fig. 3 Neural network learning process

We experimentally decided that the suitable value of \( mse \) is \( J = 10^{-4} \). To train a neural network, we used 6 input vectors \( e \), which corresponded to the 6 radar target classes. The learning process consisted of 9 epochs, and \( mse \) got the value of \( 4.09 \cdot 10^{-6} \). The obvious learning process is depicted on Fig. 3.

### 2.4 Median filter

The median filter calculates the median value of the values of classes obtained by neural network processing. The median is the 50th percentile of a sample and is a robust estimate of the center of a sample of data, since outliers have little effect on it.

An integer-rounded median gives the class of a classified target.

### 3. Experimental results

As mentioned early, our radar target classification is based on an analysis of a non-coherent radar signal. The signal was sampled at the receiver output. The radar parameters are as following

- Pulse width: 400 ns
- Pulse repetition frequency: 4 kHz
- Frequency band: J
- Sampling period: 50 ns
- SNR: 16 dB.

The classification of each radar target utilized 100 consecutive repetition periods. Values of a neural net-
work output (classes of a target) were processed by the median filter. Then the output of the median filter was integer rounded and gave the number of the class, which the radar target belonged to.

On Fig. 4 and Fig. 5 we show a percentage of classification (in 100 repetition periods) given at the output of a neural network without the median filter. Depending on SNR and fluctuation of radar-cross-section the classification process can give incorrect decision.

In the presented examples the targets were classified by the median filter into the classes No. 2 and No. 3. (In these cases the same results could be obtained on the basis of percentage mentioned above and depicted on Fig. 4 and Fig. 5.)

4. Conclusion

Results, listed in Tab. 1, confirmed our hypothesis of the exploitation of the median filter and the feed forward neural network that uses a back-propagation learning algorithm in case of a non-coherent radar.

The average success of the classification without median filter was 84.6%. The value is sufficient and corresponds to the results published in [3], [4]. The higher percentage of an incorrect classification of the targets No. 3 and No. 4 results from a higher fluctuation of a radar-cross-section.

Classification success with median filter was 100%.

As original results, we define: the use of a neural network for radar target classification in case of a non-coherent radar; determination of signal training-set; and application of the median filter.

<table>
<thead>
<tr>
<th>Without median filter</th>
<th>Correct classification [%]</th>
<th>Incorrect classification [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>Class 2</td>
<td>98</td>
<td>4</td>
</tr>
<tr>
<td>Class 3</td>
<td>59</td>
<td>42</td>
</tr>
<tr>
<td>Class 4</td>
<td>58</td>
<td>3</td>
</tr>
<tr>
<td>Class 5</td>
<td>97</td>
<td>4</td>
</tr>
<tr>
<td>Class 6</td>
<td>96</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>With median filter</th>
<th>Median</th>
<th>Class number of unknown target (integer rounded median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>0.992</td>
<td>1</td>
</tr>
<tr>
<td>Class 2</td>
<td>1.997</td>
<td>2</td>
</tr>
<tr>
<td>Class 3</td>
<td>2.986</td>
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<td>Class 4</td>
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<tr>
<td>Class 6</td>
<td>5.989</td>
<td>6</td>
</tr>
</tbody>
</table>

Tab. 1 Experimental results of radar target classification using a neural network and median filter

References