RADAR TARGET CLASSIFICATION USING NEURAL NETWORK AND MEDIAN FILTER

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Abstract

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

$$\mathbf{x}_k = \begin{bmatrix} x_{k1} & x_{k2} & \cdots & x_{kN} \end{bmatrix} \quad (1)$$

where N stands for the number of samples and $k = 1, .., K$ is the number of the observation period. Also we can define a data matrix $\mathbf{X}$ 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.

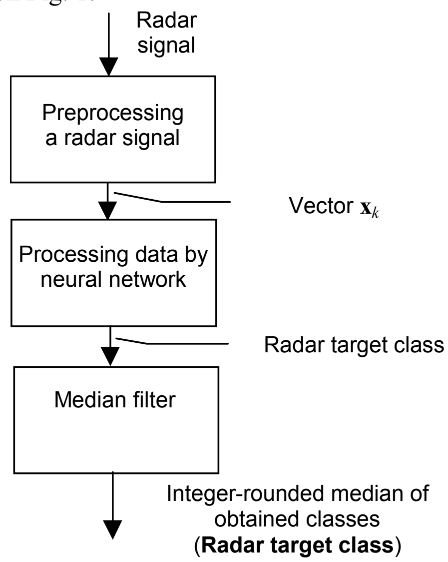

Fig. 1 The structure of the classification process

Preprocessing a radar signal includes a digitization of signal and generation of the vector $\mathbf{x}_k$.

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.

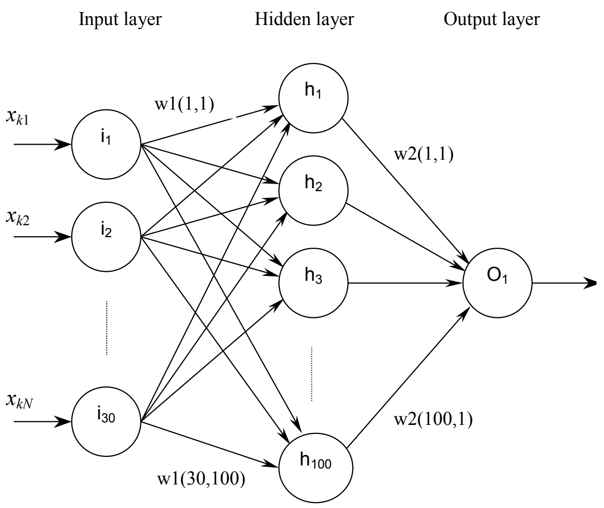

Fig. 2 The topology of a neural network used for radar target classification

The first layer called the input layer is fed by the radar target data vector $\mathbf{x}_k$, 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

$$\mathbf{c} = [\bar{c}_1 \quad \bar{c}_2 \quad \dots \quad \bar{c}_N] \tag{2}$$

where $\bar{c}_n = \frac{1}{K}\sum_{k=1}^{K} c_{kn}$.

The vector **c**, 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 **c** (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

$$err(t) = d_i(t) - u_i(t) \tag{3}$$

The purpose of learning is to minimize the *mse* [2]

$$J = E\left[\frac{1}{2}\sum_{t} err^2(t)\right] \tag{4}$$

We experimentally decided that the suitable value of *mse* is $J = 10^{-4}$. To train a neural network, we used 6 input vectors **c**, 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.

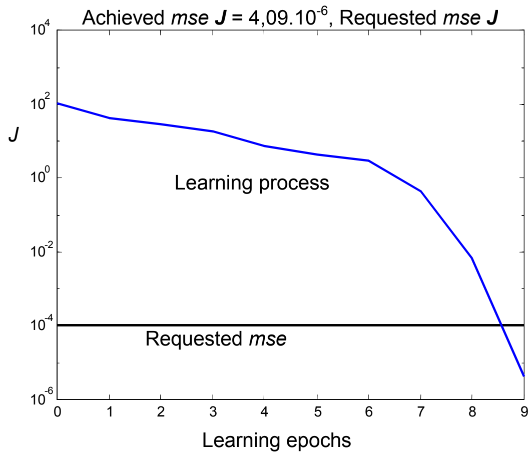

Fig. 3 Neural network learning process

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 network 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.)

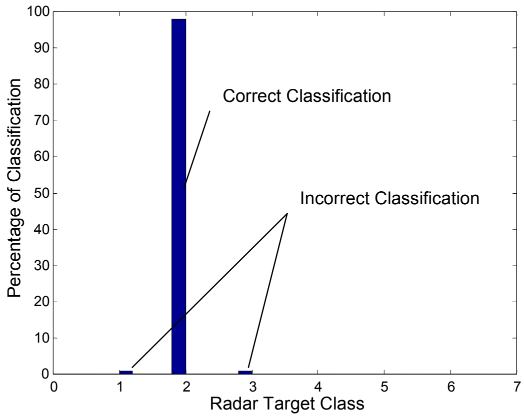

Fig. 4 Percentage of radar target classification into class No. 2

The classification of radar targets of all the 6 classes was performed by means of PC Pentium III, 450 MHz, 256 MB RAM, and MATLAB 5.3. The experimental results are presented in Tab. 1. Because the learning process is conducted before a real use of radar, the required learning time causes no time limitation. The real time during classification process is in the order of seconds up to tens of seconds. Therefore there also isn't a time constrain due to a capability of today computers.

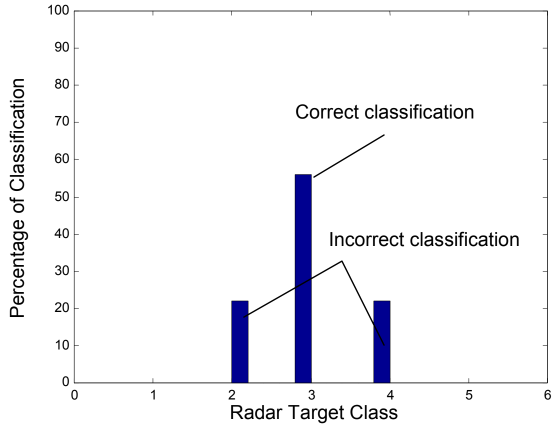

Fig. 5 Percentage of radar target classification into class No. 3

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.

		Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Without median filter	Correct classification [%]	100	98	59	58	97	96
	Incorrect classification [%]	0	2	41	42	3	4
With median filter	Median	0.992	1.997	2.986	3.924	5.027	5.989
	Class number of unknown target (integer rounded median)	1	2	3	4	5	6

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

References

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