

# The priority assignment for detected targets in multifunction radar

Wojciech Komorniczak, Tomasz Kuczerski, and Jerzy F. Pietrasinski

**Abstract** — In a multifunction radar there is necessity to manage its very limited resources. This management should concern, among others, detected targets importance description. So information of those with lower priority will be refreshed more rarely. Presented paper describes system that assigns ranks for all detected objects in real time and then puts targets in order of priority. The system is based on structure of artificial neuron. Methods of neuron learning are discussed.

**Keywords** — multifunction radar, target identification, priority assignment, resources management.

## 1. Introduction

The multifunction radar (MFR) is a device that can detect and then track many targets. Because of limitations concerning available radar resources (in a domain of time and energy) MFR should be equipped with advanced resource management system. With reference to detected objects the task of management system is, among others, to rank targets in order of their increasing priority. The ranking procedure is necessary because in situation when a lot of objects are detected, the MFR resources will be assigned to those with the highest priority. As a result of this attitude the information about targets with lower rank will be refreshed more rarely.

There are no publications related to detected objects priority assignment. Therefore, on the basis of tactics of air forces and from the other hand anti-aircraft defense, following features of objects were recognized as important from the point of view of ranking procedure:

- membership (friend or foe),
- flight direction,
- diagonal range,
- altitude,
- radial velocity,
- azimuth,
- acceleration.

One of the units of the MFR resource management system (Fig. 1) is a priority assignment module.

Generally, the structure mentioned above shows model of a MFR resource management system. The input data source

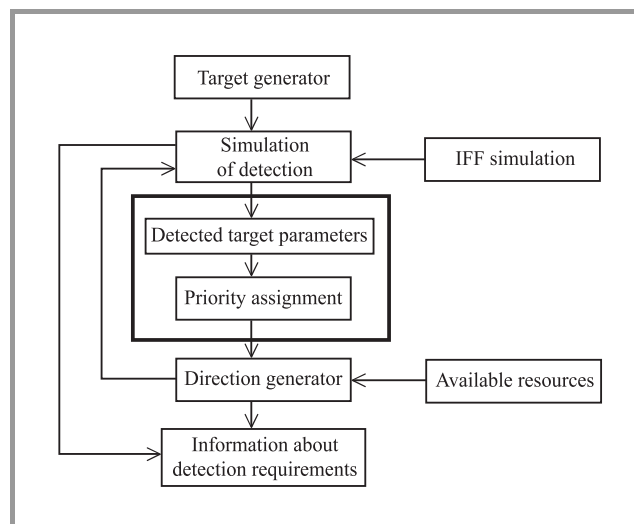


Fig. 1. The MFR resource management system model.

is target generator. The detection and IFF simulation modules approach the model operation to real conditions.

## 2. The priority assignment module model

Features of detected targets listed above can be transformed to related signals. The signals determine the input vector that is formed in the detected target parameters module. The example vector  $x_i$  can be as follows:

- $x_1$  – diagonal range [km],
- $x_2$  – radial velocity of object [m/s],
- $x_3$  – signal: friend ( $x_3 = 0$ ), foe ( $x_3 = 1$ ),
- $x_4$  – acceleration of object [m/s<sup>2</sup>],
- $x_5$  – object rank ( $x_5 = 0.5$ , in case when object is pointed by upper command, can assume value  $x_5 > 0.5$  for important one or  $x_5 < 0.5$  for not important).

As it is shown in Fig. 2, components of  $x$  vector are multiplied by weights  $w_i$  in the W-block. Then the input stimulation signal is calculated as a weighted sum of  $x$

$$u = \sum_{i=1}^5 w_i x_i. \quad (1)$$

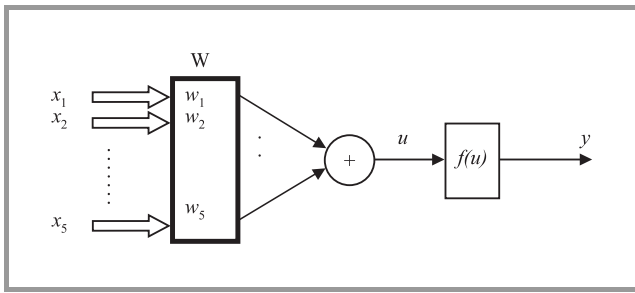


Fig. 2. The priority assignment module.

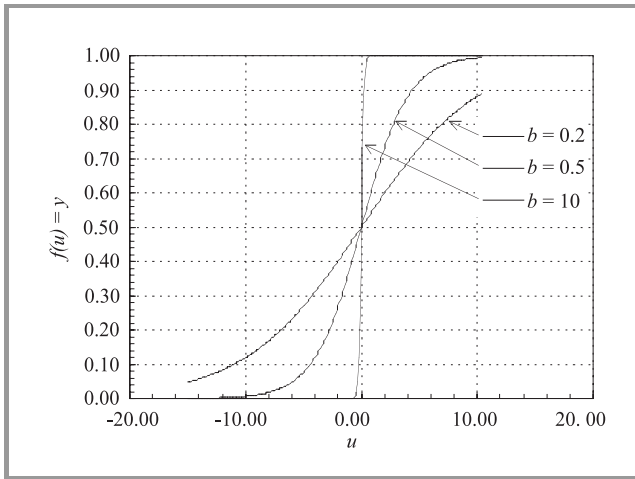


Fig. 3. Activation function of the module.

On the output of module there is a nonlinear operation  $f(u)$  according to activation function (2) (Fig. 3):

$$f(u) = \frac{1}{1 + \exp(-bu)}. \quad (2)$$

The slope of the function depends on the parameter  $b$ . The value of  $b$  will be fixed on the testing stage. For parameter  $b \rightarrow \infty$  there is the function in a form as follows:

$$f(u) = \begin{cases} 1, & u > 0 \\ 0.5, & u = 0 \\ 0, & u < 0 \end{cases}. \quad (3)$$

### 3. Weight coefficients calculation method

Due to application of the structure presented in Fig. 2 with nonlinear output element, to calculate values of the weight coefficients it is possible to use learning method with back propagation [2]. This method relies on minimizing of mean square error that arises on output. It can be defined as:

$$q = \frac{1}{2} \sum_{j=1}^N (\delta^{(j)})^2, \quad (4)$$

where:

$$\delta^{(j)} = z^{(j)} - y^{(j)},$$

$z^{(j)}$  – requested value of the target rank in  $j$ th step of learning,

$y^{(j)}$  – output value of the target rank calculated in  $j$ th step of learning for  $w^{(j)}$  weight coefficients:

$$y^{(j)} = f\left(\sum_{i=1}^5 (w_i^{(j)} \cdot x_i^{(j)})\right), \quad (5)$$

$N$  – number of learning pairs:  $\langle x^{(i)}, z^{(i)} \rangle$ ,

$U$  – learning set,

$$U = \langle\langle x^{(1)}, z^{(1)} \rangle, \langle\langle x^{(2)}, z^{(2)} \rangle, \dots, \langle\langle x^{(N)}, z^{(N)} \rangle\rangle. \quad (6)$$

According to gradient method of error  $q$  minimizing it is possible to apply weight coefficients calculating algorithm on the basis of the learning set as follows:

$$w_i^{(j+1)} - w_i^{(j)} = \Delta w_i^{(j)} = -\eta \frac{\delta q^{(j)}}{\delta w_i^{(j)}}, \quad (7)$$

where  $\eta$  is the learning coefficient.

Starting values of weight coefficients are fixed randomly. It is possible to set the weights to  $w_i = 0.5$ . It is important to assure the same conditions for the training results comparing.

The weight coefficients selection algorithm ensures the minimization of the error  $q$  for established learning set  $U$ . Because of the structure mentioned above and learning methods are compatible with nonlinear neuron model and nonlinear neuron learning algorithm [2], system has ability to generalize the target rank. Thanks to it there is a possibility to assign the priorities for all objects, even those not included in learning process. The next stage consists of verification such a module as a part of MFR resource management system.

It is worth to pay attention that the module has ability to acquire the knowledge during operation with real targets. In the case of wrong defined rank value, the system operator can manually set the requested  $z$  value and repeat learning according to algorithms (4) and (7).

### 4. Learning sets generating methods

Learning set  $U$  described by Eq. (6) consists of value pairs that input signal and requested output signal value  $z$ . Generation of this can be performed in two ways:

a) simulation method with using target generator (Fig. 1),

b) using registered real signals.

Both methods require operator – expert. He uses its own knowledge and experience, on the basis of information  $X$  shown on, for example, radar display and finally can rank the targets according to their importance. Due to established model (Fig. 3) of output signal, the rank of each

target is a number from range (0, 1). A block diagram of learning sets generating method of sets  $U$  is presented in Fig. 4.

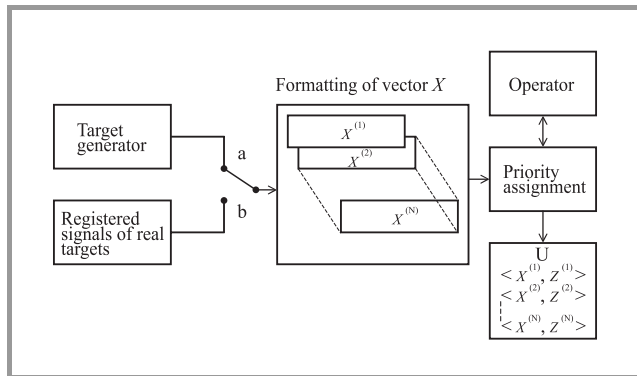


Fig. 4. Learning sets generating model.

In the case of simultaneous occurring of  $N$  targets on radar display the operator has to put them in order by assigning to each object the value of the rank  $z$ . Estimation of the minimum size of the learning set  $N_{\min}$  can be assumed on the basis of the literature [1]. It is equal twice number of all weight coefficients of module. For input signal defined as a vector of 5 elements  $N_{\min} = 10$ .

## 5. Conclusions

The proposed structure of the module (Fig. 2) enables correct realization of the priority assignment process. It has ability to learn due to possibility of weight coefficient  $w_i$  correction according to learning algorithm (8). For effective program work the learning set must be complete. It must fulfil requirements as follows:

- each input signal class must be presented;
- the learning data must consist of several subgroups relating to specific pattern;
- in each class its statistical changeability must be considered; for example the error of target parameters measure;
- to avoid excessive adaptation, the learning data must be put in random order; the value of  $N$  must not excess  $N_{\min}$ .

The learning process should be realized for many various data sets, but with using the same starting point. After each learning, it is important to save values of weight coefficients for verification using testing set of large number of elements. In the case of not satisfying error  $q$  level the module must be rebuild. It can be done for example by using cascade learning algorithm proposed by Fahlman [1].

## References

- [1] S. Osowski, *Neural Networks*. Warszawa: WNT, 1996 (in Polish).
- [2] R. Tadeusiewicz, *Neural Networks*. Warszawa: AOF RM, 1993 (in Polish).

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