METHODS OF END-USER CLASSIFICATION OF HYDROACOUSTICS SIGNATURES

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Paper presents problem of choosing methods which should be able to give end-user classification. Two methods are discussed in this paper. First of all the technique of neural networks is proposed to solve problem of und-user classification. The mathematical description of learning process as well as detail description of calculation process were presented. Secondly the fuzzy logic is proposed to solve end-user classification problem. The main processing blocks of fuzzy model as well as algorithms of calculation were in detail resented. At the end some results of using both methods as end-user classifiers based on results acquired in previous investigation were presented.

INTRODUCTION

Classification is a procedure in which individual items are placed into groups based on quantitative information on one or more characteristics inherent in the items (referred to as traits, variables, characters, etc) and based on a training set of previously labeled items. According to this definition classification should end with information about name of group in which has the highest probability that analyzed object belongs to.

In this paper the hydroacoustics signatures classification is understood as the process of automatically recognition what kind of object is generating acoustics signals on the basis of individual information included in generated sounds. We assume the hydroacoustics signatures are generated by moving ship and it is possible to acquire this signal using special measuring systems.

The classification process generally consists of creating some kind of pattern for a given group of objects and then applying the appropriate mechanism for comparing the current signal with all available patterns. Based on this comparison we should be able to determine to which pattern analyzed signal is best similar and accept that the object which generate this signal will be representative of that group. Often a comparison is to check how the parameters describing the signal being analyzed are within certain limits. In this case, specify that the parameter falls within the range or does not fit is insufficient and information about how to fulfill the assumption can decide about classification correctness. Therefore we are looking for methods that allow to determine the final decision to classify the object to the group. Among the last methods are becoming more popular methods of artificial intelligence in particular neural networks and fuzzy logic. So whole system of ship recognition-classification can be presented as on figure 1.

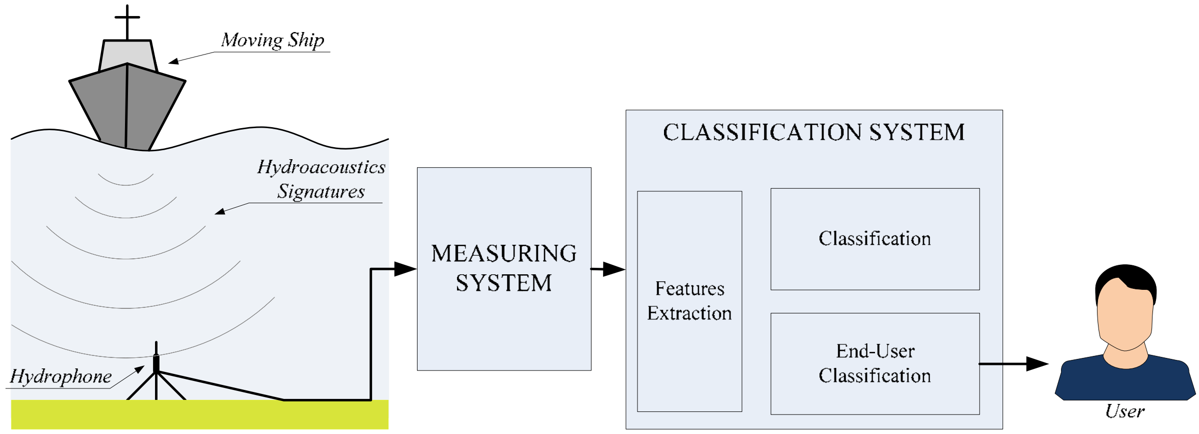

Fig.1. System of hydroacoustics signatures classification.

The classification process is often an intermediate result obtained in the form of various types of collection of information. A good example are here the self-organizing maps as Kohonen neural networks which as a result of their actions return a map of an object belonging to a certain considerations area. We must notice that using Kohonen's neural networks in classification as a results gives maps of membership in which each activated region is connected with particular ship. But basing of these results we can't say anything about type of ship because we don't know in which region of membership maps will be particular ship associated. Of course after many cycles of calculations person which is supervising classification will be able to say which type of ship is connected to given region of maps. But on introduction we were assuming that classification will be made automatically so we must use so kind of end-user classifier which will be able to answer the question what is the name of type of ships which is generated acquired hydroacoustics signature. To do this we can use neural network to connect activated regions in membership maps acquired form Kohonen's network with particular name of type of ship or use fuzzy logic which can say about probability that ship belongs to the one of the groups of ships.

1. END-USER CLASSIFICATION USING NEURAL NETWORKS

Feedforward neural networks are the most popular and most widely used models in many practical applications. Neural networks consist of artificial neurons which are the systems with many inputs and one output. Each neuron performs a weighted summation of the inputs, which then passes a nonlinear activation function, also called the neuron function (see figure 2). Mathematically the functionality of a neuron is described by [1, 3]:

$$y_i = f\left(\sum_{j=1}^{N} w_{ij} x_j\right) \tag{1}$$

where: y is the output of i-th neuron, w denotes the weight vector, x is the input vector, $f()$ denotes activation function.

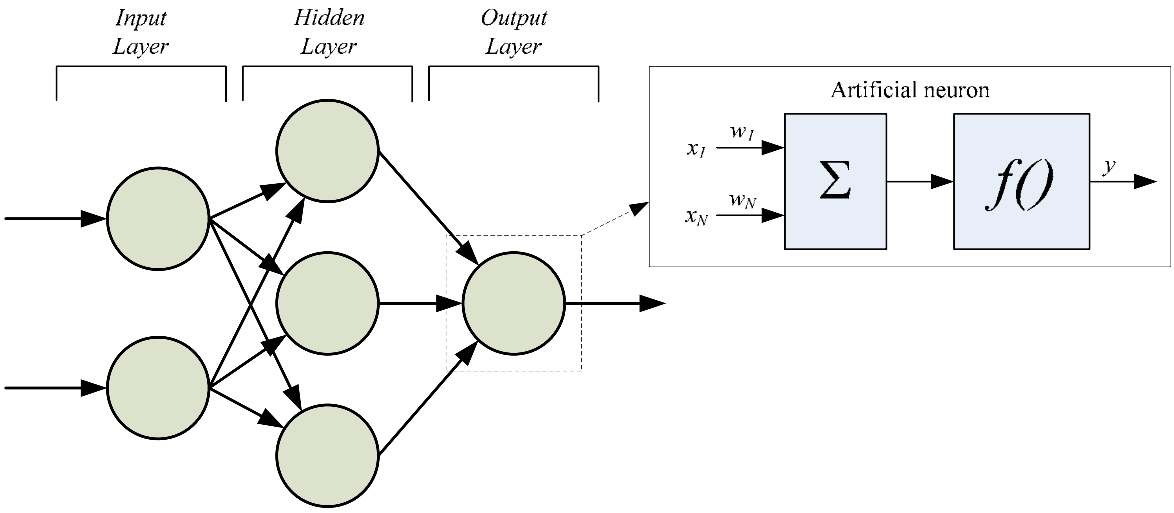

Fig.2. Feedforward neural network and artificial neuron.

The activation functions can be any differential function. Most common is used standard sigmoid function. The variables w for each neuron are the parameters of the network model that can be represented collectively for whole neural network by the parameter vector Θ.

The network is divided into layers. The input layer consists of just the inputs to the network. Then follows a hidden layer or layers, which consists of any number of neurons. The network output is formed by the output layer. Generally, the number of inputs depend on length of input vector and number of neurons in output layer equals the number of outputs of the approximation problem. During creating architecture of feedforward neural network the problem is to determine numbers of hidden layers and number of neurons in each hidden layer. This problem can be solved using Vapnik-Chervonenkins rules [1].

Given a fully specified network, it can be trained using a set of data containing N input-output pairs (x, z) where x denotes input vector and z desired values of output of neural network. With this data the mean square error (between calculated output of neural network and desired values) is defined by [1]:

$$E(\Theta) = \frac{1}{N}\sum_{i=1}^{N}\left(y_i(k) - z_i(k)\right)^2 \tag{2}$$

Then, a good estimate for the parameter is one that minimizes the MSE that is [1]:

$$\Theta = \arg\min_{\Theta} E(\Theta) \tag{3}$$

The various training algorithms that apply to feedforward networks have one thing in common—they are iterative. They start with an initial parameter vector Θ_0, which is generated using random function. Starting at Θ_0, the training algorithm iteratively decreases the MSE by incrementally updating along the negative gradient of the MSE, as follows [1]:

$$\Theta(k+1) = \Theta(k) - \eta R \nabla_{\Theta} E(\Theta) \tag{4}$$

where: the matrix R may change the search direction from the negative gradient direction to a more favorable one, η is the learning rate.

The purpose of parameter η is to control the size of the update increment in Θ with each iteration i, while decreasing the value of the MSE.

There are few algorithms of training neural networks for example the most popular are: Backpropagation, Levenberg-Marquardt, Gauss-Newton, Steepest-descent. The basis method is backpropagation algorithm which is similar to the steepest descent algorithm with the difference that the step length η is kept fixed during the training. Hence the backpropagation algorithm is obtained by choosing $R = I$ in the parameter update in (4). The MSE calculated for output layer if propagated back from the output layer through hidden layers to the input layer, and become basis to determine changes of neural network parameters Θ. The training algorithm may be augmented by using a momentum parameter μ. According to this the new algorithm is [1, 3]:

$$\Theta(k+1) = \Theta(k) - \eta R \nabla_{\Theta} E(\Theta) + \mu(\Theta(k) - \Theta(k-1)) \tag{5}$$

The idea of using momentum is motivated by the need to escape from local minima, which may be effective in certain problems. In general, however, the recommendation is to use one of the other, better, training algorithms and repeat the training a couple of times from different initial parameter initializations.

2. END-USER CLASSIFICATION USING FUZZY LOGIC

Fuzzy logic is a form of many-valued logic or probabilistic logic which deals with reasoning that is approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions [2].

Fuzzy logic provides convenient design of nonlinear systems, especially when the nature of the nonlinearity makes it difficult to describe their analytical methods. The structure of a typical fuzzy model is shown on the figure 3 [2].

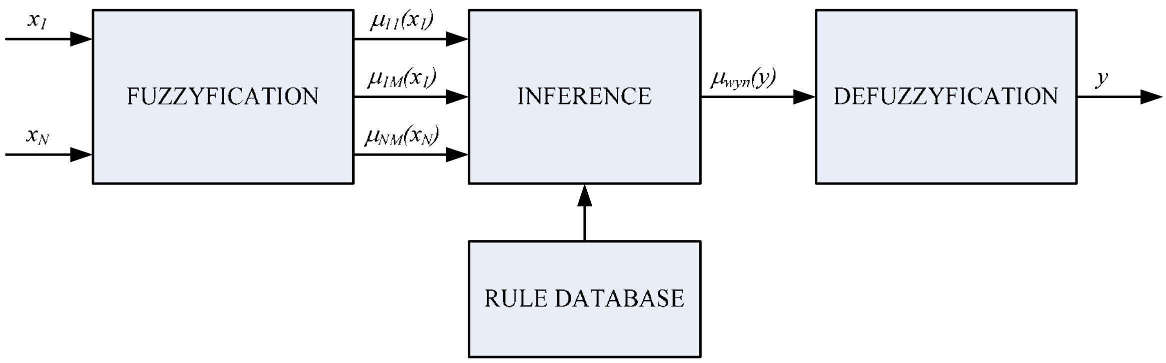

Fig.3. Fuzzy model.

The fuzzy model inputs are introduced in the block of fuzzyfication as crip numerical values x. In fuzzyfication block blurring operation is performed which consists of the calculation of the degree of membership for crip numerical input values for each input fuzzy sets A, B. To realize this operation fuzzyfication block must have clearly defined membership functions $\mu_A(x_1)$, $\mu_B(x_2)$ to the fuzzy sets for the individual inputs. The calculated and reported in the output value of the degree of membership inform how high is membership of crip numerical input values, in this case, x_1, x_2 for each input fuzzy sets. The example membership functions are presented on figure 4.

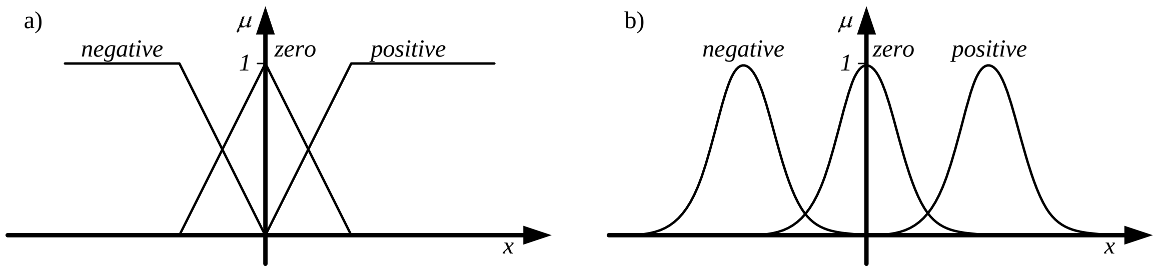

Fig.4. Example membership functions a) triangular, b) Gaussian.

In inference block there is calculated so-called the resulting model output membership function basis on the input membership degrees. This function has often complex shape, and its calculation is done through the implementation of the so-called inference or otherwise conclusion that can be mathematically implemented in many ways. Block of inference is using the knowledge which is collected in rules database.

The database contains the logic of rules defining the cause-and-effect relationships existing in the system between fuzzy sets of inputs and outputs. This database is usually in the form of rules expressed in the form “If ... then ...”. Database is often presented as the rule matrix which is build basis on expert knowledge and represent all possible combination of inputs and outputs.

Inference mechanism performs the task of calculating the resulting membership function. This mechanism performs the following calculation [2]:

- the degree of compliance with the conditions of individual rules;
- the degree of activation of the conclusions of individual rules;
- determine the resulting form of input membership function based on the degree of activation of the conclusions of individual rules.

In the defuzzification block, basis on the results output membership function, is calculated crip numerical output value. This value can be used as input to other traditional logic system. Calculations are made according to one of chosen way for example using methods of: middle of maxima, first of maxima, last of maxima, center of gravity, height method or others.

3. RESULTS OF RESEARCH

Researches concentrated on checking the correctness of working proposed end-user classifier were based on the results obtained in previous studies of classification methods presented in [3, 4]. During research the five ships were measured on the Polish Navy Test and Evaluation Acoustic Ranges which schema was presented on figure 1. Ships No. 1 was minesweeper project 206FM, ship No. 2 was minesweeper project 207D, ship No. 3 was salvage ship project 570, ship No. 4 was minesweeper project 207P, and ship No. 5 was racket corvette project 1241RE.

In research was used neural network end-user classifier as well as fuzzy end-user classifier. Neural network end-user classifier was a second layer of neural classifier based on Kohonen’s network. In this experiment as end-user classifier was used 3 layers feedforward neural network (one input layer, one hidden layer and one output layer) which seems to be enough. The value of learning rate was set up at 0.3 and momentum rate at 0.65. With this parameters the possibility to classification (number of correct answers, speed of learning and minimum number of neurons) was the best. After about 5 000 cycles of neural network learning, end-user classifier seems to work stability it means that number of correct answers on output was above 80 %.

In research was also used fuzzy end-user classifier. The input area was divided onto 6 parts using two membership function in y-direction and three in x-direction as a membership function - Gaussian functions (see figure 5a, 5b). As a output membership function was used singletons one for each group of ships (see figure 5c). The matrix rule has form as on figure 5d.

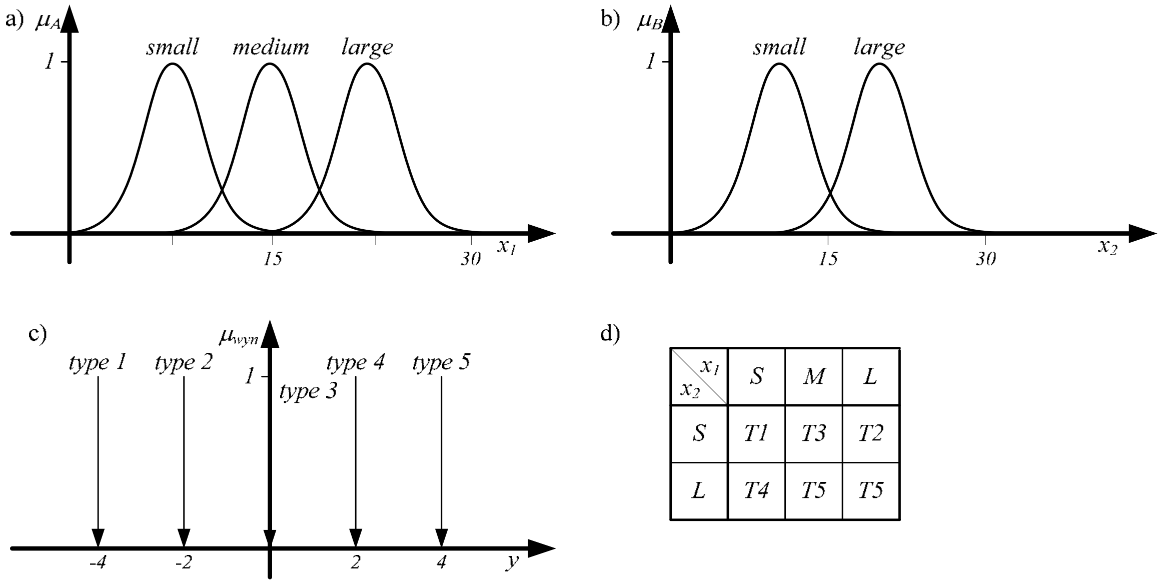

Fig.5. Fuzzy end-user classifier a, b) input membership functions, c) output membership functions, d) the rule matrix.

During research there were observed number of correctness answers according to whole answers of classifier. According to type of used end-user classifier the results of classification differs what can be observed on table 1. As it is shown neural network end-user classifier gives worse results. This was dictated by the classification errors on the stage of creating maps of membership using Kohonen's neural networks as well as errors caused by neural en-user classfier. Theoretically fuzzy end-user classifier should give 100% correct answers but it must be noticed that errors are made on stage of membership maps generation by Kohonen's network. The creation of fuzzy end-user classifier was much more easier and faster, because there were no need to conduct teaching process as in neural network end-user classifier but expert must know which activated by ship region belongs to which type of ship. More over increasing the number of recognized type of ships forces to reorganize fuzzy end-user classifier it means the number of inputs membership functions and number of singletons on output membership functions must change.

Tab.1. Results of classification – number of correct classification.

Type of method of end-user classification	Ship number				
	1	2	3	4	5
Neural network	86 %	88 %	84 %	86%	89 %
Fuzzy logic	92 %	93 %	91%	93%	95%

4. SUMMARY

In paper there are presented two methods of end-user classification problem solving. Both methods represent a class of artificial intelligence methods. Thanks to this their application is based largely on the teaching process, as in the case of neural networks or expert knowledge as in the case of fuzzy logic. Both of them has its own advantages and disadvantages. Selecting one of them to solve a particular problem should be preceded by an analysis of the relevance and benefits of its use. In presented example, it seems that the grandest is to apply the methods of artificial neural networks as logical continuation of classification process. In classification problems where it is important to consider several criteria at once it should be easier to use fuzzy logic. An additional advantage of fuzzy logic is that it use the expert knowledge which allows for a description of the cases. In other hand many. On the other hand, many decision variables may lead to the inability to describe all cases and in this cases it should be easier to use neural networks which build its own knowledge during teaching process. However as it was shown both of proposed methods are suitable to carry out the end-user classification.

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