Hybrid Neural Network based on models of Multi-Layer Perceptron and Adaptive Resonance Theory

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Abstract. **The model of the hybrid neural network is considered. This model consists of model ART-2 for clusterization and perceptron for preprocessing of images. The perceptron provides invariant recognition of objects. This model can be used in mobile robots for recognition of new objects or scenes in sight the robot during his movement.**

I. Introduction

Application of model Adaptive Resonance Theory of Grossberg-Carpenter [1] (in particular ART-2) is rather attractive to problem of solving of classification and clusterization, because this model combines in itself properties of plasticity and stability, and also it does not demand a priori knowledge of the fixed quantity of necessary classes. Many different modifications of this model and its combinations with other neural networks are known [2,3,4,5]. One of hybrid model of neural network based on model ART-2 and perceptron with error back propagation training algorithm are suggested in this paper.

Model ART-2 has essential disadvantage. It assumes usage of only one layer of neurons (not including entry, associated with sensors). It results to that the neural network works only with the metrics of primary features and calculates distance between images (for classification or creation of a new cluster - output neuron), using usually Euclidean distance. It results to that for many applications the model ART-2 is a little used. For example, for clusterization and pattern recognition by the mobile robot [6] it is required to recognize the object in different foreshortenings and allocating in different parts of a field of vision, i.e. recognition should be invariant concerning conversions of the map, such as shifts, rotations and others.

Invariancy of recognition provide multilayer perceptrons because in them on intermediate layers in learning process secondary features are forming. It is possible to tell, that in perceptrons each layer provides conversion of one metrics to another.

In this report the hybrid model is offered. It combines of advantages of multilayer perceptron with learning by error back propagation [7] and model ART-2.

II. Hybrid model of the neural network

In suggested model the first some layers of neurons are organized as perceptron with forward connections. Its outputs are inputs of model of Grossberg-Carpenter ART-2. Perceptron provides conversion of the metrics of primary features in the metrics of secondary features in space of considerably smaller dimension. Neural network "ART-2" classifies images and uses secondary features to do it. Training of perceptron by back propagation algorithm provides "attraction" of an output vector of perceptron to centre of recognized cluster by ART-2. It is possible to tell, that the recognized class is a context in which other images from learning sampling are recognizing, and in some limits the system “is ready to recognize” it and in the further until then in learning sampling the input vector of perceptron will be converted to a vector very much distinguished from vector - centre of "cluster-context".

Action of the suggested model is described by the following algorithm in which training without the teacher is realized:

1. In the perceptron the weights of links equal to half of quantity of neurons in the previous layer are formed. The quantity of output neurons N_{out} of ART-2 is considered equal zero.
2. The next example is shown. Outputs of perceptron are calculating.
3. If N_{out}=0, it is formed output neuron with the weights of links equal to values of inputs of model ART-2 (outputs of perceptron).
4. If N_{out}> 0, in model ART-2 the algorithm of calculation of distances between its input vector and centers of existing clusters (weight vectors of output neurons) is executing:

$$d_j = \sqrt{\sum_i (x_i - w_{ij})^2} ,$$

where: x_i – i^{th} digit of input vector of ART-2,
w_{ij} – i^{th} digit of weight of j^{th} output neuron (cluster).

If distance for the neuron-winner more than defined R value (vigilance or radius of cluster), the new cluster as well as in step 3 is formed.

5. If the distance for the neuron-winner is less R in model ART-2 weights of links for the neuron-winner are enumerating, approximating centre of a cluster to the input vector of model ART-2:

$$w_{im} = w_{im} + (x_i - w_{im})/(1 + N_m) ,$$

where: N_m – number of recognized input vectors of m^{th} cluster.

And for perceptron recalculation of weights by algorithm “error back propagation” (EBP) are executing. Thus a new vector of weights of output neuron-winner of model ART-2 is viewed as output vector-example for EBP, and the quantity of iterations can be little (in particular, there can be only one iteration).

6. The algorithm repeats from step 2 while there are learning examples.

Action of the suggested model is explained in a figure 1.

Here the space of secondary features in which by points are represented output vector perceptrona (input vector of model

ART-2), centers of clusters are shown. In a figure the following points are represented:

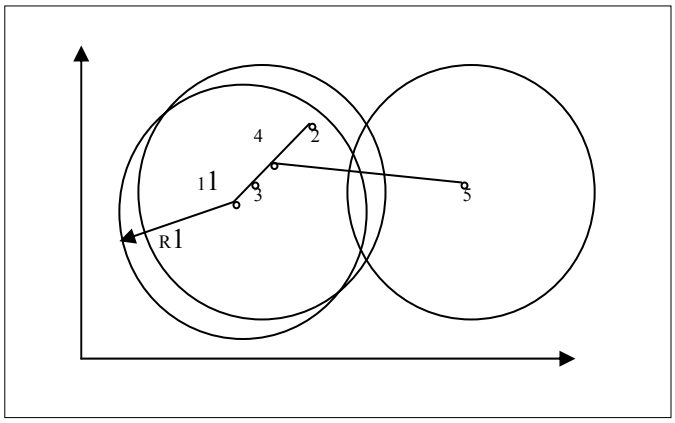

Figure 1. Explanation of action of hybrid model

1 - a new image for which the cluster with radius *R* is created,

2 - the new image recognized as concerning to this cluster,

3 - the new centre of a cluster calculated in step 5 of algorithm,

4 - a new output vector of perceptron, approximated to centre of a cluster as a result of executing of algorithm "error back propagation",

5 - the new image recognized as inhered to other cluster.

III. Experiments

For research of the suggested model the program of generation of a sequence of patterns with shift on one of axes and the program model of the neural network handling this sequence of patterns has been developed. In a figure 2 two examples of images used in experiments are shown.

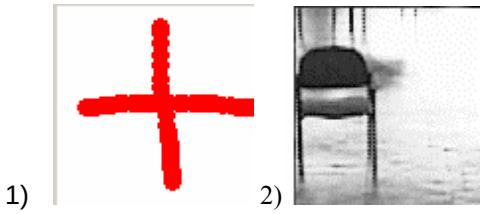

Figure 2. The images used in experiments

The suggested algorithm of training without the teacher in experiments has shown good results at rather minor changing of each next example in a taught sequence. Thus the following parameters of model have been used:

Quantity of input neurons (pixels) - 10000 (100x100),

Quantity of neurons in hidden layer of perceptron - 10,

Quantity of neurons in an output layer of perceptron (in input layer of ART-2) N_{out} - 10,

Radius of cluster $R = 0.01$,

Activation function of neurons of perceptron is rational sigmoid with parameter a=1,

Number of iterations of recalculation of weights of perceptron is from 1 to 10.

Some results of experiments are shown in figures 3 and 4.

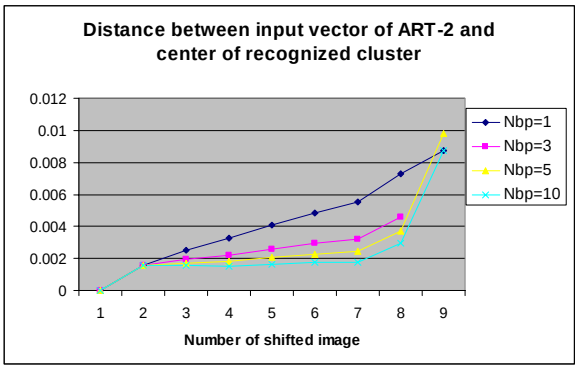

Figure 3. For sequence of image 1 with horizontal shift

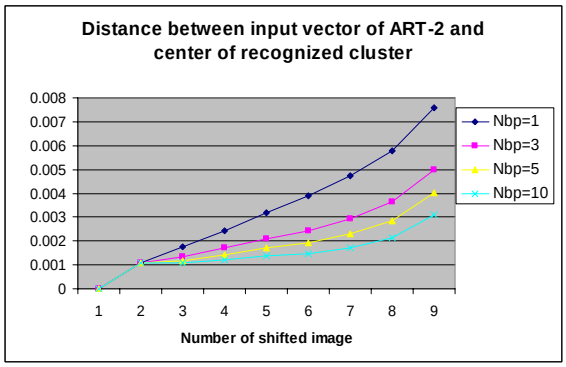

Figure 4. For sequence of image 2 with horizontal shift

IV. Conclusion

The suggested hybrid model of the neural network can be used in the mobile robot when it is necessary to watch sequence of the images visible by the robot during its movement, and to extract in it new images (objects), i.e. essential changes in the scene visible by the robot. More over, this model may be used in security systems for recognition of new objects or persons in sight of camera. Modification of this algorithm can be algorithm in which the quantity of created clusters is limited. In this case, if the quantity of clusters (output neurons) has achieved a limit, arises the problem what to do with images which are not recognized, i.e. which cannot be related to any existing cluster. In this case may be offered increase of parameter R (radius of clusters) and to try to apply again algorithm of recognition and so until the new image will not be related to one of clusters. After that, it is necessary to reduce quantity of clusters (output neurons), uniting clusters with the centers which appear in one cluster, and accordingly changing weights of links between outputs of perceptron and outputs neurons-clusters.

Modification of this algorithm can be algorithm of training with the teacher in whom before to apply the procedure of increase of radius and decrease of quantity of output neurons, the system requests "teacher" what to do - to apply this procedure or to create a new cluster. As "teacher" there can be not only inquiry to user, but also any additional test for novelty of an image.

The following further researches of the suggested hybrid

model of the neural network are planned:

- A mathematical substantiation of suggested algorithms,
- Research of influence of perceptron and ART-2 parameters on results of action of the neural network,
- Testing of the suggested model on program model of the mobile robot and the real robot,
- Research of various modifications of algorithm of hybrid model.

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