Ensembles in Neural Networks

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Abstract

We present the results of the neural network (NN) investigation. The NN contains the neural ensembles (NE) that are formed during NN training. NE is a set of neurons with connections among them and the connection weights are stronger than between other neurons. Every ensemble presents one entity, for example, any characteristic, a feature, an object, any relation. The main problem is how many ensembles we can save in the NN with possibility to recover them from a part of information. We investigate the NN information capacity. We describe the experiments and give the results of this investigation. The main conclusion of the investigation is that we can save and restore the NEs and the number of these ensembles can be more than a NN neuron number. This type of NNs can be used in recognition tasks of different situations and as an element of decision making system.

1. Introduction

One of the tasks where we can use this type of neural networks is the manipulator control system. In this paper we will consider the movement of a manipulator to make automatically a wire board prototyping. The technology of wire board prototyping was proposed in [1]. In the Fig.1 the example of wire board is presented. This sample was made manually. Now we develop the technology of automatic "sewing" of the wire board.

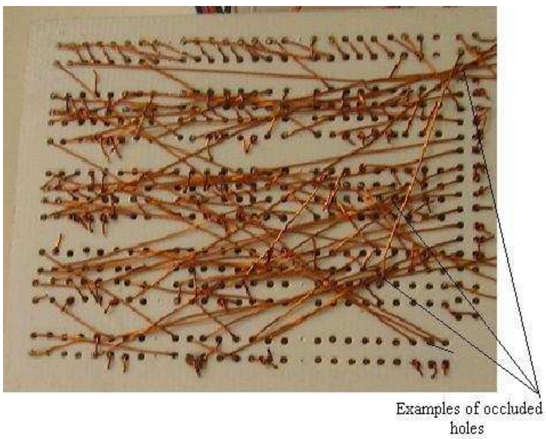

Figure 1: Example of wire board prototype.

In Fig. 2 we present the system for automatic assembly of these wire boards.

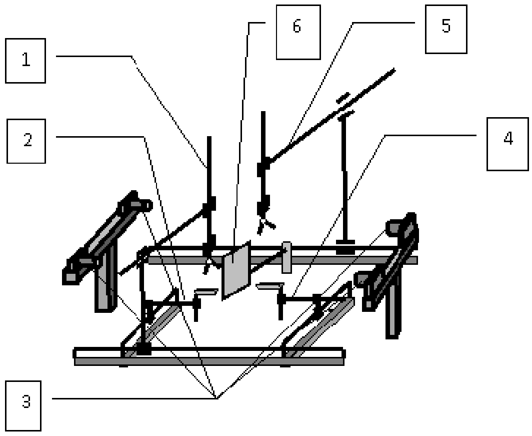

Figure 2: The system of wire board automatic manufacture.

In Fig.2: number 1 corresponds to manipulator with 6 degrees of freedom, number 2 is manipulator with 3 degrees of freedom, number 3 is four Web cameras, number 4 is manipulator with 3 degrees of freedom, number 5 is a manipulator with 6 degrees of freedom, and number 6 is a electronic board with the support.

The robot-manipulators may be manipulators for automatic assembly with collision-free trajectory planning [2], [3]. In this case the robot needs to have a set of maneuvers and use one of them when a simple movement is impossible. The number of such maneuvers can be very large. Sometimes it is impossible or impractical to enumerate all the maneuvers, to give a description for each one and store all this information in memory. We propose the use of ensemble neural networks to represent the robot maneuvers and to store them in computer memory.

Different types of ensemble neural networks were developed [4] - [9]. This paper contains a brief description of ensemble neural networks and the principles of maneuver representations in such networks. It is very important to develop neural networks that can store a large number of maneuvers in compact form. In the case of ensemble neural network each maneuver corresponds to one neural ensemble. We developed the program to estimate the number of neural ensembles that can be stored in the neural network with a determined number of neurons. Experiments with this program show that the number of ensembles can be much larger than the number of neurons.

2. Description of the "sewing" process

The automatization stages of sewing process of a wire board are presented in the following figures. In Fig.3 the process to connect the grooves with magnet wire is demonstrated, where number 6 is a plastic board; number 7 is a pair of holes; number 8 is a groove between two holes; number 9 is a magnet wire; number 10 is the grip 1 of manipulator 1 (Fig.2); number 11 is the grip 2 of manipulator 5 (Fig.2).

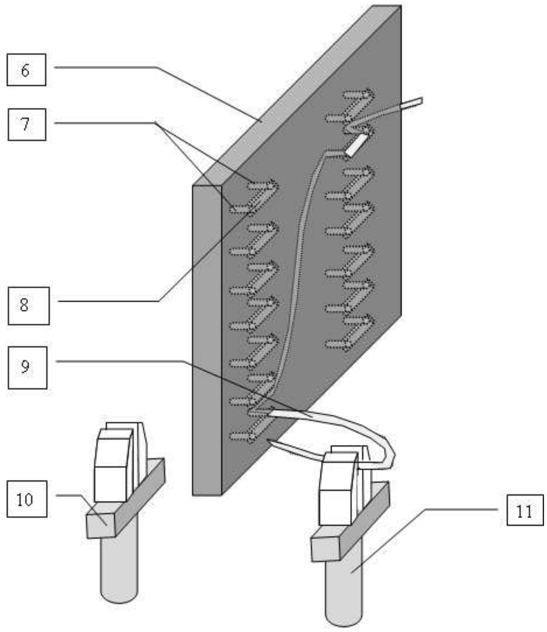

Figure 3: Process to connect the grooves with magnet wire.

In Fig.4 the process of the magnet wire installation into the hole where 6 is a plastic board; 7 is a hole; 9 is a magnet wire; 10 is the grip 1 of manipulator 1; 11 is the grip 2 of manipulator 5; L_1 is a distance of the grip 2 until magnet wire terminal; L_2 is a distance of the grip 1 until magnet wire terminal.

The process of hauling the magnet wire through the hole is presented in Fig.5, where 6 is a plastic board; 7 is a hole; 9 is a magnet wire; 10 is the grip 1 of the manipulator 1; L_1 is a distance of the grip 2 until magnet wire terminal; L_2 is a distance of the grip 1 until magnet wire terminal.

Fig.6 demonstrates the use of the grip 2 to recover the distance until the magnet wire terminal (6 is a plastic board; 7 is a hole; 9 is a magnet wire; 10 is the grip 1 of manipulator 1; 11 is the grip 2 of manipulator 5; L_1 is a distance from the grip 2 until magnet wire terminal; L_2 is a distance from the grip 1 until magnet wire terminal.

Banding the magnet wire and introducing its terminal to another hole is presented in Fig.7, where 6 is a plastic board; 7 is a hole; 9 is a magnet wire; 11 is the grip 2 of manipulator 5; L_1 is a distance from the grip 2 until magnet wire terminal.

Fig.8 demonstrates the whole system that contains television cameras, a special guide for magnet wire to introduce the magnet wire to a hole, where 6 is a plastic board; 7 is a pair of holes; 8 are the grooves; 9 is a magnet wire; 10 is the grip 1 of manipulator 1; 11 is the grip 2 of manipulator 5; 3 are four Web cameras; 13 is the magnet wire guide for manipulator 4.

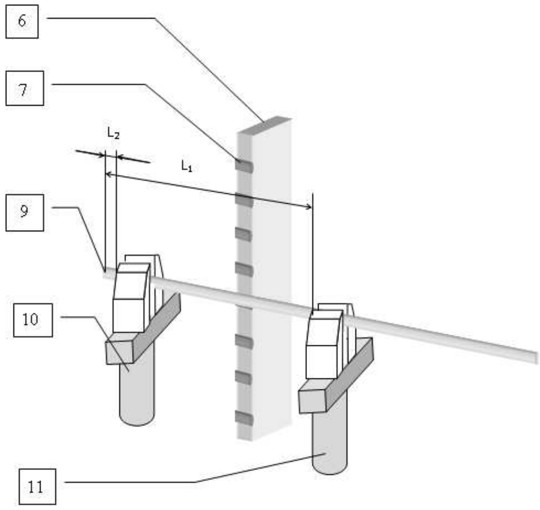

Figure 4: Magnet wire installation into the hole.

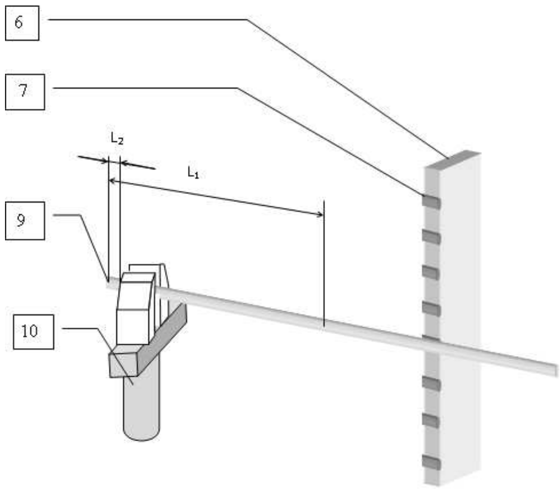

Figure 5: Hauling the magnet wire through the hole.

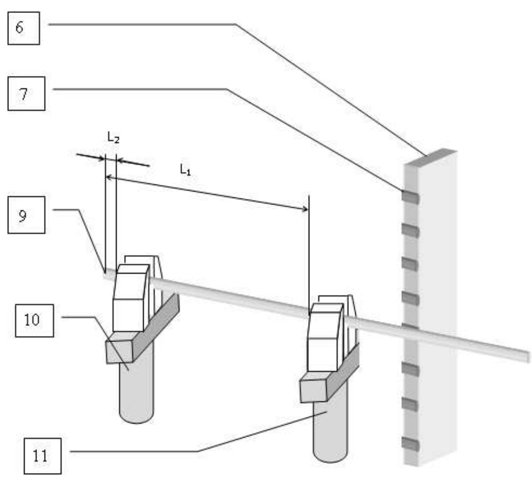

Figure 6: Use of the grip 2.

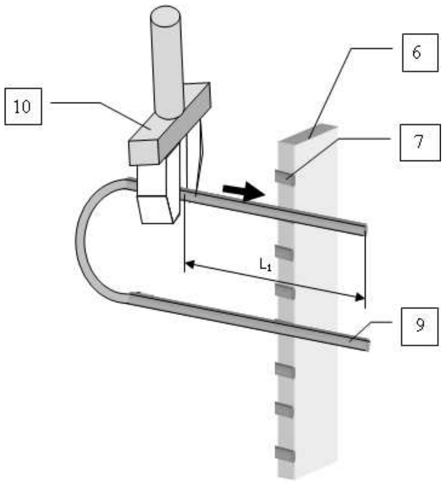

Figure 7: Banding the magnet wire.

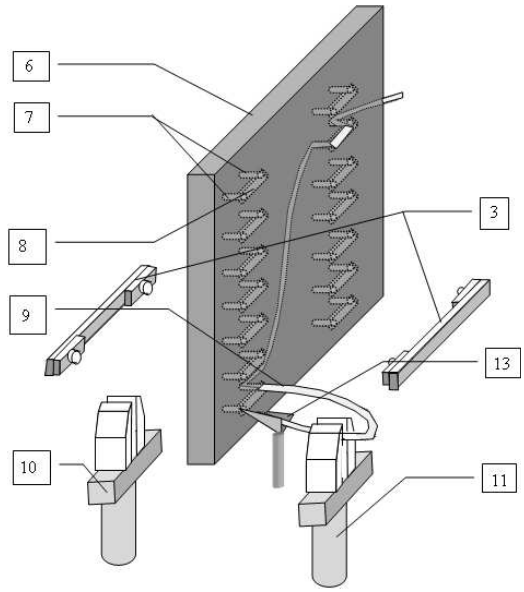

Figure 8: Banding the magnet wire.

To do automatically all these operations with magnet wire and wire board we have to recognize many situations with our four cameras. Every element of the situation can be presented as an ensemble in neural network.

3. Neural ensembles

The NN contains the neural ensembles (NE) that are formed during NN training. NE is a set of neurons with connections among them and the connection weights are stronger than between other neurons. During training, two active neurons are connected with trainable connection. The weight of the connection increases, if both neurons are exited in the same time interval. If the same vectors are input to the network several times, the weights of connections forming between the active neurons will increase. Thus, in the network are formed the sets of neurons having higher weights of connection than the mean weight of connection in the remaining network. We term such sets the neural ensembles [4].

In the ensemble, it is possible to distinguish the nucleus and fringe [4], [5] (Fig.9). Let the ensemble containing the neurons 2, 3, 4, 5 was previously formed. Let us add new neural ensemble which contains the neurons 3, 4, 5, and 6. After excitation of these neurons we will have synaptic matrix presented in Fig.9. Neurons of the ensemble having a higher weight of connection correspond to the nucleus.

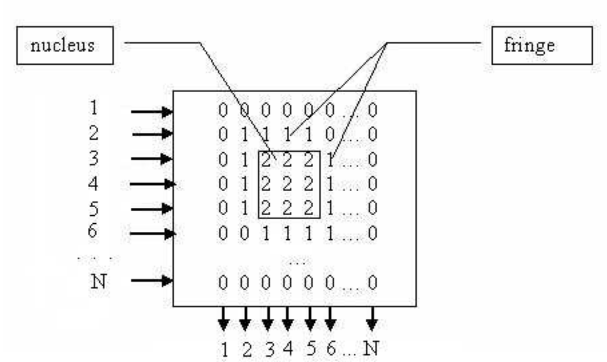

Figure 9: Ensemble structure.

The most typical information about the presented object corresponds to the nucleus. The individual properties of the representatives of the object class correspond to the fringe. If we select the different quantities of neurons with the greatest activity, for example, those assigning a high threshold of neural activity, then we can ensure a different level of concretization in the description of the object. For example, if the nucleus of the formed ensemble is named “pear,” the extended description (taking into account the neurons entering the fringe of the ensemble) can contain the information “yellow, pear-shaped, medium”.

It is possible to train NN with neural ensembles where each neural ensemble will present one maneuver of manipulators in the wire board assembly device. It is very important to develop the NNs that can store large number of maneuvers in compact form. The manipulator needs to have the set of maneuvers and use one of them when the simple movement cannot give a good result. The number of such maneuvers can be very large. We propose to use ensemble NN to represent the manipulator maneuvers and to store them in computer memory.

We developed computer program to estimate the number of NEs that can be stored in the NN with determined number of neurons (N). Experiments with this program show that the number of ensembles can be much larger than the number of neurons.

4. Results of NN information capacity investigation

To estimate the storage capacity we wrote special program. In this program the independent random ensembles that have m neurons are created in the neural network that has N neurons [10]. The possibility to restore the ensembles was proved as follows: in each ensemble 50% neurons were eliminated and substituted with the neurons randomly selected from the network (50% noise). After that the ensembles were input to the network. If at the output of the network we have the ensemble that contains 90% of neurons of initial ensemble, we say that the network restored the ensemble correctly.

The results of experiments with the program are presented in Table 1, Table 2. With bold fonts we mark the cases of maximum number of correctly restored ensembles for different ensemble sizes. The maximum number of ensembles we obtained in cases when the number of retrieval errors less than 1%.

Table 1: NN with N=28 000

Number of Ensembles	Ensemble Size (m)	Retrieval Errors
180 000	64	622
190 000	**64**	**1228**
120 000	32	632
150 000	**32**	**1472**
160 000	32	1984
16 500	**24**	**161**
18 000	24	561
12 000	**15**	**72**
13 000	15	143

Table 2: NN with N=40 000

Number of Ensembles	Ensemble Size (m)	Retrieval Errors
400 000	64	3039
410 000	**64**	**4125**
450 000	64	22787
290 000	**96**	**2797**
300 000	96	4684

5. Discussion

The tables show that the number of the ensembles in the network can be much larger than the number of neurons. The number of ensembles in the neural network depends on the size of ensemble. G.Palm and A.Knoblauch [11], [12] made theoretical estimations of optimal size of the neural ensembles and obtained the asymptotical value:

$$m = \ln N / \ln 2 . \quad (1)$$

For our case N=28 000 (Table 1) m=14.8. The closest integer is 15. In the Table 1 we see that for m=15 the number of ensembles can be only 12 000. At the same time for m=64 the number of assemblies can be 190 000. G. Palm did not analyze the presence of noise in the input code. When we have noise it is necessary to increase the size of an ensemble to obtain optimal storage capacity.

6. Conclusions

We investigate the NN information capacity. We describe the experiments and give the results of this investigation. The main conclusion of the investigation is that we can save and restore the NEs and the number of these ensembles can be more than a NN neuron number. This type of NNs can be used in recognition tasks of different situations and as an element of decision making system.

7. Acknowledgements

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8. References

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