Study conclusion mechanisms in hybridization of neural and logic intelligent systems

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Abstract. The paper investigates the integration problems neural networks sections allocated in accordance with the functions performed. As an initial example, we study two trained neural matrices, one of which performs the function of recognizing the position of the manipulator and its speed, and the second generates responses using the corresponding robot drives. In addition to training mechanisms based on the adjustment of transfer weights, the mechanisms based on the supply of excitation / inhibition waves from the edges of the neural network are also affected. At the same time, training is reduced to multiple forced guiding of the robot manipulator along the target path, during which the desired paths of beatings are automatically found using comparators. The matrices are trained separately and then joined using a standard signal generated by a special unit. The division of the neural network into two sections allows building the necessary logic between them. This hybridization significantly expands the range of tasks. As a test problem, the task of searching for a given part from a jointly located set of parts in general position was selected. At the same time, the control system finds a given part, rotates its predetermined model until a matching image is obtained, and thereby understanding how the part is located and how best to capture it occurs.

1. Introduction
At present, neural networks are often used in practice as an effective artificial intelligence tool [1]. This is caused by the speed of processing a large amount of information due to parallel processes in them, as well as a wide range of tasks, the solution of which they can be trained with the required accuracy. However, in practice, networks that can be called single-stage are more often used, that is, the network is a kind of information processing channel, the initial information is input and the result appears on the output. Some studies nevertheless use sections of the network that are allocated according to a functional basis [2,3].

2. Theory
Hybridization of intelligent technologies is quite developed. However, it can be interpreted in different ways - for example, in [4] it is associated with a decision-making procedure by a diverse group of specialists. It can be related to the complexity of the tasks and can be very different when predicting the behaviour of time series based on a modular neural network [5] or detection of objects for image analysis based on convolutional neural networks proposed in 1989 by Yann LeCun, which gave a second life to neural network theory [6].

F. Rosenblatt, who proposed the idea of a perceptron, understood it as a universal model of the whole brain [7]. However, medical studies show that the brain is nevertheless divided functionally.
The possibilities of a functional approach in technology were studied in [3], where local neural networks were applied to simulate the process of annealing a zinc strip, to search for technologically rational temperature settings in the zones of the heating section and to form actions applied to the input of the actuator.

Another way to isolate local sections of the neural network is using the so-called convolutional networks. This use of a local receptive field for each neuron of the convolutional layer, the formation of convolutional layers in the form of a set of cards, the neural elements of which have the same synaptic connections, and the presence of subsampling layer cards, increase the network invariance to distortions [8-10]. The general architecture of the convolution network is shown in Figure 1.

The advantage of the "island" application of neural networks is the ability to insert logical elements between the islands, that is, it creates hybrid neural-logical networks, which greatly expands the range of tasks.

![Figure 1. LeNet-5 Network Architecture [1].](image)

3. Model
We study the functional separation of sections of the neural network into the matrices of trained neurons, used in [2] (Figure 2). Two matrices are distinguished in the device, one of which performs the functions of technical vision, it can be called recognizing (in Figure 2 on the left), the second, let's call it responsive (in t Figure 2 on right), implements responses, setting the magnitude and direction of movement of the manipulator using the drives. The device is first taught a matrix that implements the necessary reactions, forming the driving signals using a special block of standard signals (in the figure 2, number 18). Then, repeatedly repeating the necessary trajectory of the manipulator, the first matrix is trained, achieving at its outputs signals that are identical with the standard signals using comparators (in the figure 2, number 17), forming positive or negative reinforcements in training. Now the outputs of the recognition matrix can be connected to the inputs of the reacting one and a loop will be obtained in which both the given trajectory of the manipulator using neurons 8 and its speed along this trajectory are controlled due to the presence of differentiating chains in the synapses of the trained neurons 10. If there are any irregularities in the field of view of the recognition matrix, for example, foreign objects or an increase in environmental resistance (for example, clinging to any fabric, wire tension), the manipulator will be stopped or it will restart.

Another mode of operation of the device can be implemented if we create a set of all possible reactions of the manipulator in this scenario of behavior. All that remains is to train the recognition matrix so that it outputs exactly those signals that correspond to the manipulator reaction adequate in the given conditions. Such a system will realize conditional reflexes, as it were, in contrast to the first
regime, where reflexes were formed unconditionally. It can be used to respond to detected defects in an appropriate control system [11].

Figure 2. Device for nervous system modeling

4. Data and Method
We study the features of the application of the theory to the problem of choosing and capturing details of an arbitrary arrangement. Figure 3 shows a photograph of the pin (the extreme detail on the left), while the task is complicated by the presence in the field of view of other parts of similar shape.

The control system of the manipulator must recognize the necessary part, understand its position in space and choose the method of its capture.

Two types of processing are performed in parallel in the recognition matrix. In the first case, the idea of convolutional networks that increase the invariance of the device to distortion is used. As a result, the image of the pin is recognized and the position of its geometric center is determined. At the same time, noise is eliminated by filtering the image, including from glare, and the contours of the parts are determined. Then, the contours are completed at the points of their discontinuities, as is observed at the contour end of the pin shown in Figure 4.
To complete the contours, we can apply the mechanism of cellular logic. Moreover, each pixel of the contour image of the pin in Figure 4 corresponds to its own cell with simple response rules depending on the state of the neighbors. If the neighbors are in a state of inhibition, then this cell also goes into this state and vice versa in the case of excited neighbors. Cells corresponding to the existing contour lines stop the propagation of both excitation and inhibition waves.

![Figure 3](image_url)

**Figure 3.** Figure with short caption (caption centred).

Since there are often discontinuities in the contour when the signals from the contour cells are delayed and the excitation wave goes beyond the body of the pin or, on the contrary, the drag wave enters the body of the pin, the process stops after the collisions of these waves end. Then logic is triggered, which classifies the cell as excited or inhibited, depending on most neighbors. Such logic straightens the overlaps described above.

Thus, background damping is performed due to “braking” waves sent from all edges of the image. Simultaneously, excitation waves propagate from a previously determined geometric center. As a result, in the places of collision, the outer contours of the group of parts are formed. Focusing primarily on them, the control system begins the process of understanding the scene. She turns the pin model sequentially in her memory, achieving the same look as in the image. In the geometric center, the apparent size of the cylindrical part is measured. From the similarity of triangles, the distance from the matrix to the geometric center of the pin is determined. Then, by measuring the apparent size of the length of the pin, and calculating the length of the pin located parallel to the horizontal plane at a distance that was determined a little earlier, we can determine the angle of inclination of the axis of the pin to the horizon.

![Figure 4](image_url)

**Figure 4.** Result of eliminating noise and determining contour lines (rotated 90 degrees).
The information obtained allows the control system of the manipulator to choose the location of the supply of the manipulator - in this case, on the left side, since the pin is in contact with other parts on the right, deploy the grip parallel to the axis of symmetry of the pin and knowing the distance to the pin to capture it.

5. Results and discussion

The values obtained from the recognition matrix are summarized in table 1.

| Table 1. Measurement Results |
|-------------------------------|------------------|-------------------|------------------|------------------|------------------|
| Diameter mm | Length mm | Angle vert. hail | Length meas. mm | Diameter meas. mm | angle horiz. hail |
| value | 12 | 92 | 16.26 | 125 | 17 | 8.1 |

The control system had to deploy the pin model in memory by 16.26 degrees with respect to the vertical axis of the image and by 8.1 degrees with respect to the image plane, which in turn was removed from the recognition matrix by 30 centimeters. Now the control system is looking for the reaction closest to the given one in the set prepared in advance and starts its implementation.

6. Conclusion

Thus, the study of conclusion mechanisms during hybridization of neural and logical intelligent systems leads to an efficient “island” allocation of sections of neural networks that perform a specific function and the inclusion of logically processing information subsystems between these sections, which can significantly expand the range of managerial tasks to be solved. Such hybridization has significant prospects for practical application.

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