Software Implementation of the Neural Network Controller in Systems with Complementary Correction of the Control Action

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The paper deals with the issues of software implementation of the neural network controller in automatic control systems (ACS) with complementary correction of the control action based on the modified fourth form of invariance.

The neural network controller generates an additional component in the control action in two variants:

1) autonomous, as a component to the main control;
2) correction of the control action at the stage of its generation.

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Typical representatives of systems are mobile technological robots.

Optimal and adaptive control methods with different interpretations of quality functions and control and correction algorithms are used to parry disturbances on the transport system and the technological robot.

Modification of the fourth form of invariance is based on the relationship between the control and disturbing influences in robotic systems. It is supposed to compensate for the external indeterminate disturbance by introducing an additional component into the control Δg.

The additional control is determined by $\Delta g(p) = \dfrac{M_2(p)\Delta f(p)}{B(p)}$

Let's note one more principal feature. When parrying the disturbance, the additional control must be saved, which requires the introduction of an integral component at , then

$$\Delta g(p) = \frac{M_2(p)\Delta f(p)}{pB(p)}$$

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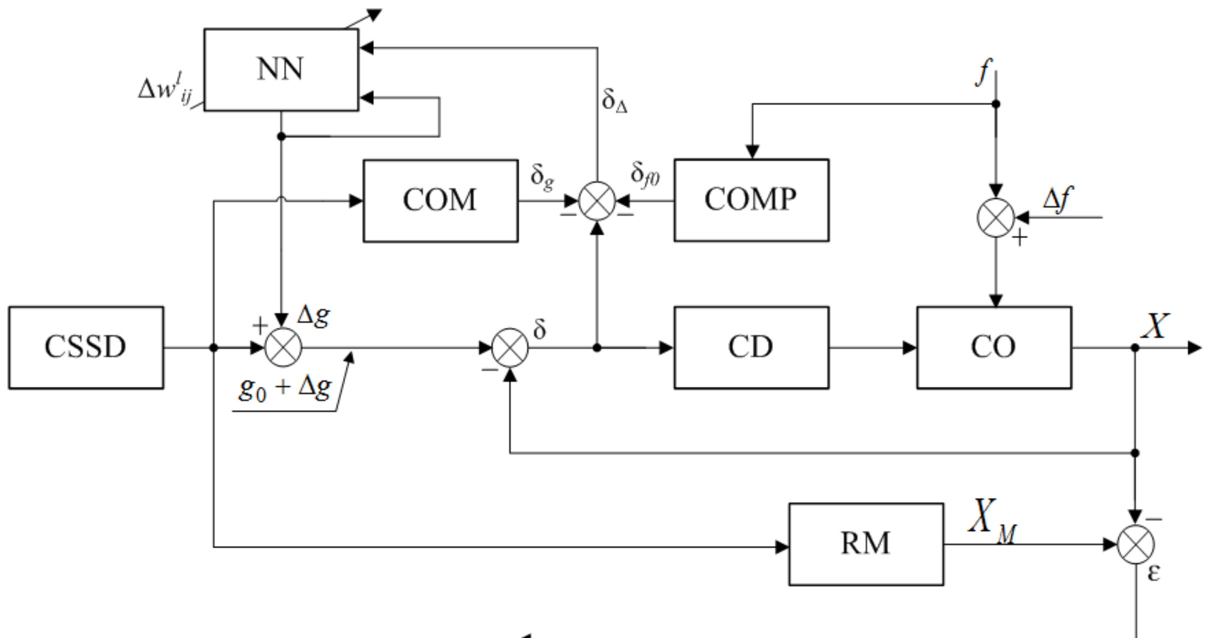
The analysis of the ACS structures with complementary correction allows us to propose diagrams for introduction of the neural network controller in the ACS loop, (Fig.1).



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The training algorithm is a set of the following actions [1], [2], [3], [5], [6]:

1. Initialize weights *W* (by small random values), select the initial η_0 and maximum η_{max} values for the training rate, control error δ.

2. Initialize Δ*W* by filling it with zeroes.

3. Calculate the error *E*(*n*).

4. If the result satisfies (|*E*(*n*)| ≤ δ), then training is not implemented, otherwise go to step 5.

5. Calculate the loss function gradient ∇*E*(*n*) on the current iteration.

6. Determine the training rate for *i*-th layer according to an expression

$$\eta\{i\} = \eta_{\max} \cdot (1 + \exp(-|R\{i\}|))$$

7. Calculate the change in parameters:

$$\Delta W(n) = \eta \cdot (K \cdot E(n) + \rho \cdot W(n\text{-}1)) + \mu \cdot \Delta W(n\text{-}1)$$

8. Network weight correction

$$W(n) = W(n-1) - \Delta W(n)$$

9. Go to step 3.

10. Introduction of the integral component of the output of the neural network *U*(n) in the control action

$$\Delta G(\mathrm{n}) = \sum_{k=0}^{n-1} U(k)$$

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Software Implementation of the Neural Network

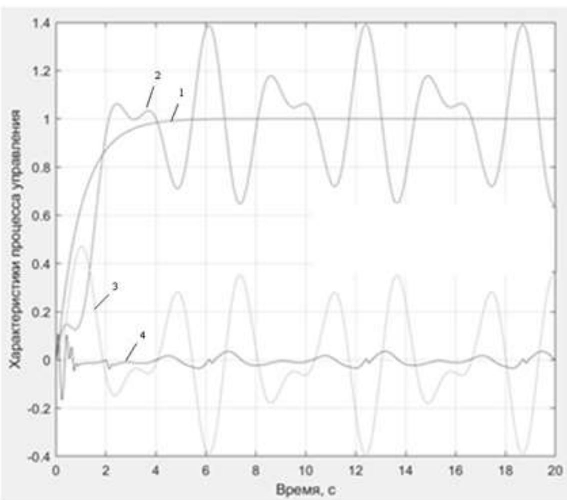
The analysis of the works showed that various simulation programs are used to create NN, but the most popular for research and design of automatic control systems for dynamic objects is MATLAB program.

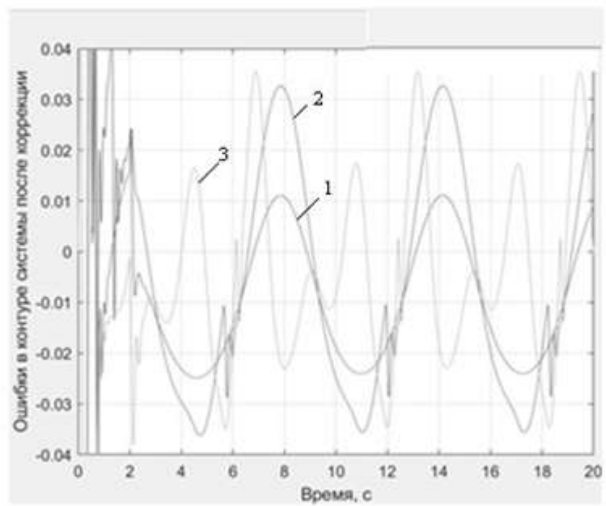
The Simulink block is definitely described by sets of input variables *u*, state variables *x*, and output variables *y*.

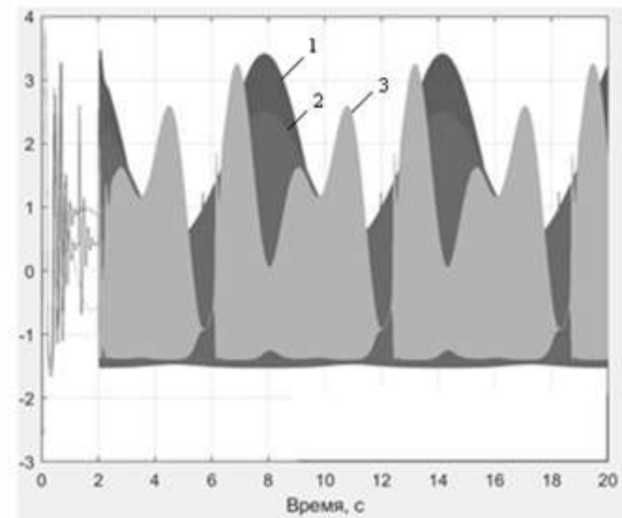
The input parameters of the block are: number of layers of the neural network; the input vector of the neural network that reflects the number of neurons in each layer; the activation function in the hidden layers of the neural network; activation function in the output layer of the neural network; sampling the neural network; speed ratio training coefficient; moment coefficient; regularization; the stop condition of the training process; the training algorithm.

Study of the System with a Neural Network Controller

The analysis and study of the designed structure of the control system, based on the neural network technology with online training, was implemented by the example of the electric drive of the robot joint with a neural network controller included in the system according to the structure shown in Fig.1







Conclusions

The basis of the designed method of neural control is the implementation of the complementary correction method and the paradigm of online training. The input of the system is additionally fed an integral of the output signal of the neural network.

When autonomously configuring a neural network, a system simulator with controlling and disturbing effects is used. When working as part of a system, the system signals are used directly for tuning. As an error signal, being used to adjust the weights of the neural network, a mismatch signal is used between the output coordinate of the reference model and the control object.

The study of synthesized controllers was carried out on the basis of the drive model of the robotic system by means of Simulink package of MATLAB program. The results of the study of the proposed structures indicate the performance of the neural controller in ACS with complementary correction of the control action.

The results obtained can be applied in practice to improve the accuracy of mechatronic and robotic systems and ACS of other types of objects and control processes.

Thank you for attention!

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