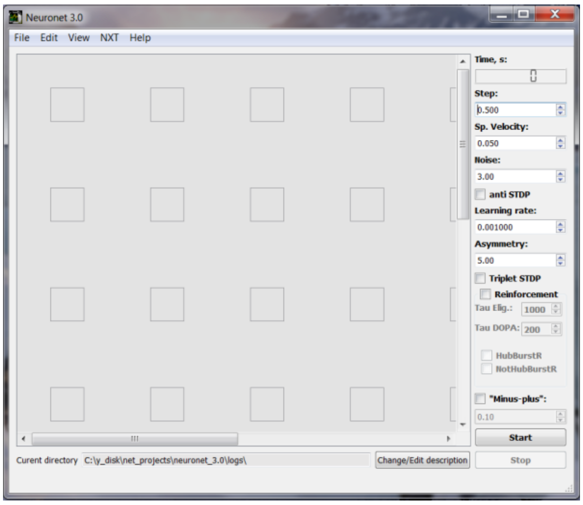
Quick Start Guide of NeuroNet

Brief description of the NeuroNet software

The NeuroNet is designed to simulate the dynamics of neural activity in networks of various sizes and configurations. The program allows you to use a model neural network to control the LEGO robot. The program uses the LIF model of neuron and the Izhikevich's model. The signal between neurons propagates taking into account axonal delays. The effects of short-term and long-term synaptic plasticity are taken into account. The graphical user interface allows you to change the network configuration in a visual-interactive mode, as well as observe and record the characteristics of neurons and the network. In addition, tools for automatic generation of neural networks are provided, the statistical characteristics of which (the number of excitatory and inhibitory neurons; the number, value and distribution of connections) are set by the user.

Launch and initial configuration of the NeuroNet



The program is launched by the **neuronet.exe executable file**. This opens the main form. The graphical interface of the Neuronet program allows you to create neural network objects and manage them in a visually interactive mode - using the mouse pointer and the context menu.

Simulation parameters such as simulation time step and plasticity type can be changed directly in the main program window to the right of the network image. The simulation time can be reset by **right-clicking on the timer** in the upper right corner of the main program window and selecting the appropriate item from the context menu.

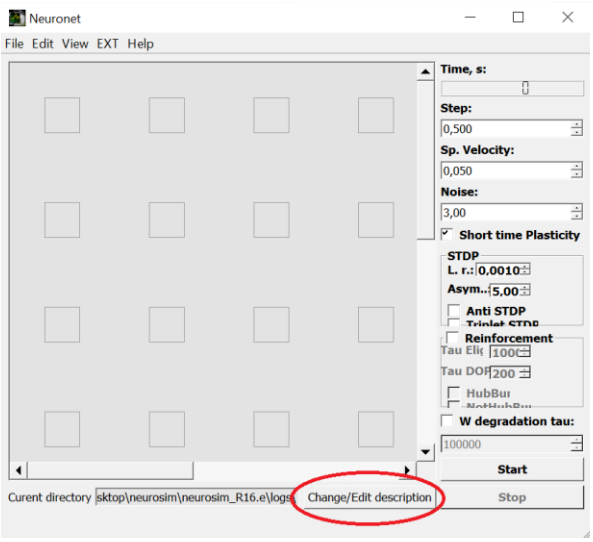
To start the modeling process, you need to press the **Start button** of the main window. During the simulation, you can observe in the form of graphs the changes in various network characteristics over time. To do this, run the main menu command **Edit → Net Characteristics.** Also, during the simulation, you can observe the change in the characteristics of individual network objects - neurons and stimulators. To display these characteristics, **double-click the left mouse button on the image of the neuron or stimulator** of interest.

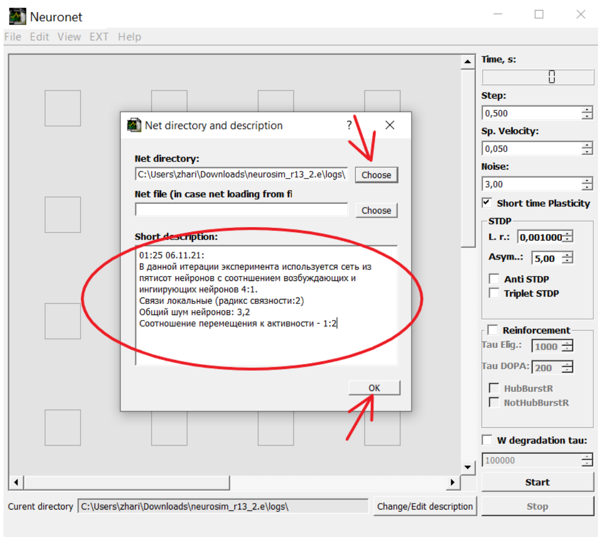
To terminate the program, you must first stop the simulation using the "Stop" button in the main program window. Next, you need to close all auxiliary windows and then close the main window.

Using a single neuron. Neuron parameters

Run the NeuroNet using the program executable file.

Select (after creating) the simulation folder and enter a short description of the protocol. To do this, click the Change/Edit description button on the main window. Enter a textual description of the proposed numerical experiment in the protocol editing form. **Choose a path by clicking Choose** in the line with the name Net directory. When you press the OK button, the data from the form is saved to a text file description.txt in the selected folder. Files (*.log) with parameters and simulation results will be saved in the same folder.

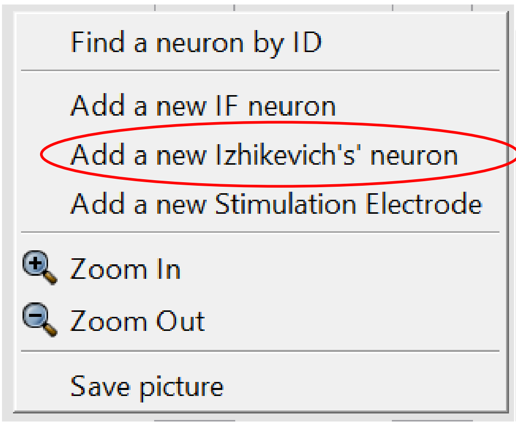


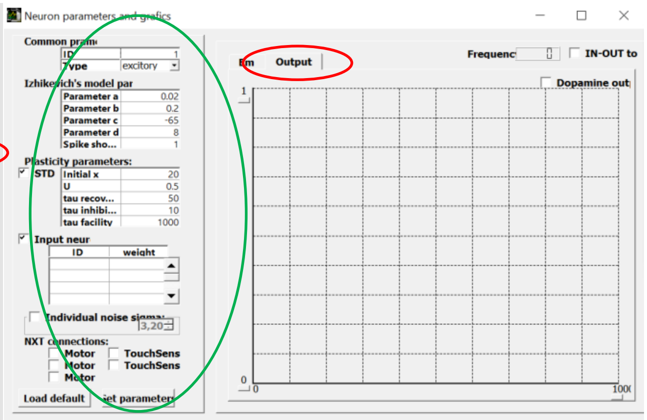


ATTENTION! If you do not explicitly assign a path to save the simulation data before running the simulation, the default path may not be correct. In this case, an error message will be displayed when trying to run the simulation.

To create a neuron, you need to **right-click** (RMB) anywhere in the graphical field of the neural network (a scalable area with squares that occupies most of the main window), and **select the Add a new Izhikevich's neuron** in the context menu that opens.

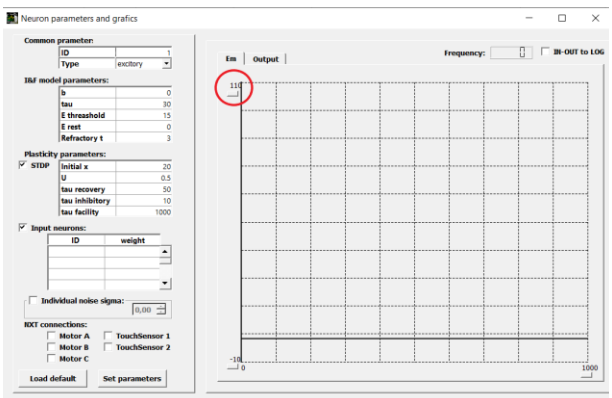
Open neuron parameters by double-clicking the left mouse button (LMB) on it. In the right part of the window that opens, **there are tabs "Em" and "Output"**, where you can observe the dynamics of the membrane potential of the neuron. In the left part of the window there are tables that describe the current parameters of the neuron transmembrane potential and short-term synaptic plasticity models.

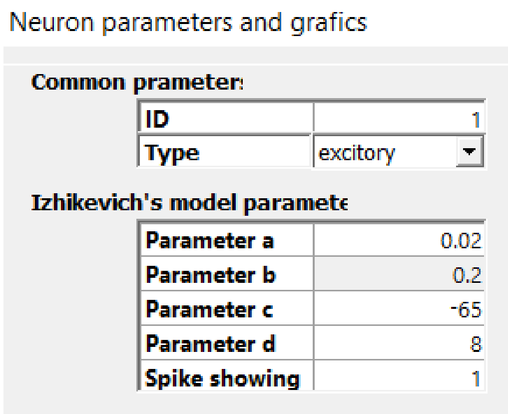




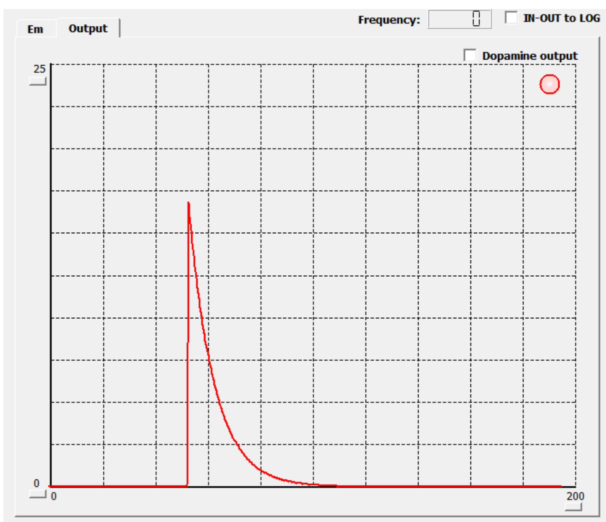
After **creating a neuron**, to **start** the simulation, **click the Start button**.

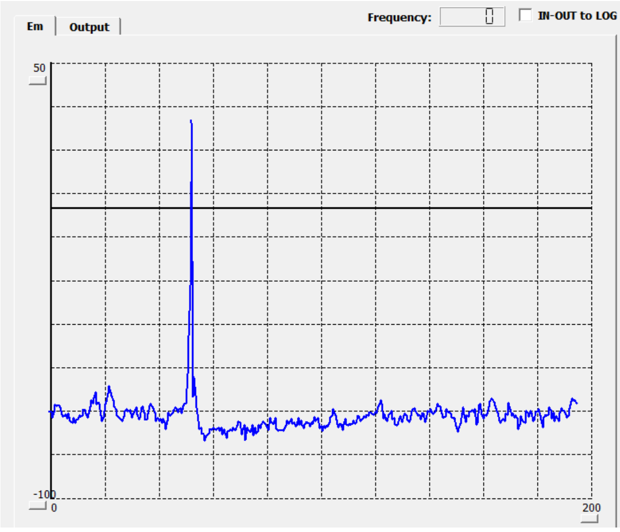
The parameters for displaying the characteristics of a neuron can be changed while the simulator is running. In order **to change the display scale** along the axes, **you must click on the rectangular button** located under the maximum value of the desired axis.





Pay attention to the table with the parameters of the Izhikevich model. The default values (a = 0.02, b = 0.2, c = -65, d = 8) correspond to the regular spiking (RS) type. The RS-neuron is at rest in the absence of external influence (current I = 0 in (1)) or in the mode of constant spike generation with an external current greater than a certain value. Accordingly, in order to excite a neuron, it is necessary to produce stimulation. For one-time stimulation, right-click on a neuron and select “Fire!” from the list that opens.





At the same time, on the “Em” and “Output” graphs, we can observe the generation of a spike and the output signal transmitted from the current neuron to other postsynaptic neurons. The output signal in the "Output" tab is presented taking into account the scaling transformation **factor g_j**. The latter, in turn, is defined in the scaling **factor g** synaptic response parameter in the plasticity parameters group.

Neural network modeling

In the neurosimulator Neuronet, a neural network can be created "manually", using a graphical interface, and in an automated way, by setting the statistical parameters of the network being created. In the latter case, in the network architecture being created, the parameters of neurons and their connections will correspond to a Gaussian distribution. At the same time, in the form of the network wizard **(wizard)**, we can set the average values **(mean)** and standard deviations **(st. deviation)** of the parameters.

Creating connections between neurons

To visualize connections in the network, click the button in the menu **View → Show connection.**

To create neural ensembles, it is necessary to connect the created neurons to each other. To connect neurons, you need to **right-click on the postsynaptic neuron**, select **"Connect to"** in the context menu, and then **left-click on the presynaptic neuron**.

Connections in NeuroNet are displayed using segments with different shades of gray, proportional to the weight of the connection w. When creating an interneuronal connection through the graphical interface, the synapse by default has **a maximum weight w = 1**, which corresponds to **black**. The dot at the end of the segment marks the neuron that is postsynaptic for this connection.

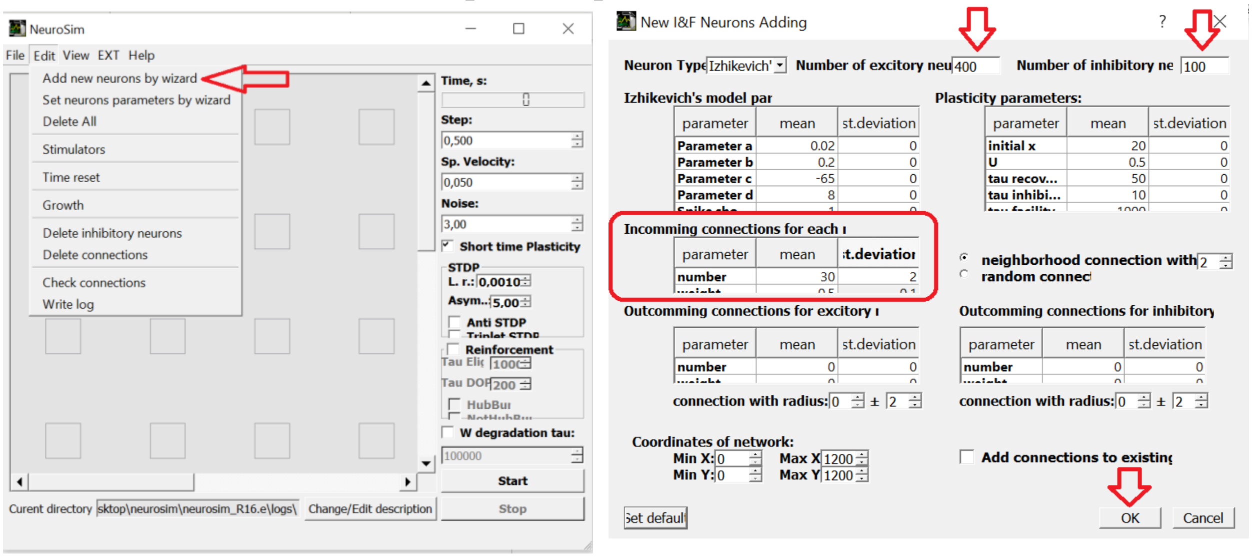
Saving and loading a neural network

To save the neural network with all current parameters and variables, use the **File → Save whole network** command. In the file selection dialog box, you must specify a name in ***.net format**. It is recommended to name the files in such a way that the main purpose and key parameter of the simulation can be understood from the name. Also, in Neuronet, you can save only the network architecture with the parameters of neurons without the current values of the variables using the **File → Save configuration** command. In this case, the file name will be ***.cfg**.

To load previously saved files with neural networks, select **File → Load whole network** in the main menu (to load the network, including the values of all variables) or **File → Load configuration** (to load the network architecture with neuron parameters without the current values of the variables).

Creation of a neural network with specific parameters

To create a network with the specified parameters, select **Edit → Add new neurons**



by wizard in the main menu. In the window that opens, enter the number of excitatory and inhibitory neurons in the required ratio, for example: 400 and 100. In the "**Incoming connections for each neuron**" submenu, **set the number of neuron connections** to 30 ± 3 (here in after, the mean ± standard deviation) in the number field. **Set the link weight** to 0.5 ± 0.1 in the weight field. Then **click OK**.

To zoom in or out, you need to **right-click in any free place** (from neurons and stimulators) in the neural network graphic field and select **Zoom In or Zoom Out**.

Network characteristics

To observe the network characteristics, select **View → Net Characteristics** from the main menu.

1. **Weights histogram.** Shows the distribution of link weights in the network. In case of inconsistency with the desired value, to adjust the connection weights, select the command **Edit → Set neuron parameters by wizard**. In the window that appears, check the **Change weights** option and set the desired link weight.

2. **Raster diagram** – displays in the form of points the moments of generation of spikes of the corresponding neurons
3. **Frequency** – average frequency of spikes in the network. To calculate it, the program first calculates the average frequency (in Hz) of each neuron:

$$f_i = \frac{1000 N_{sp}}{t},$$

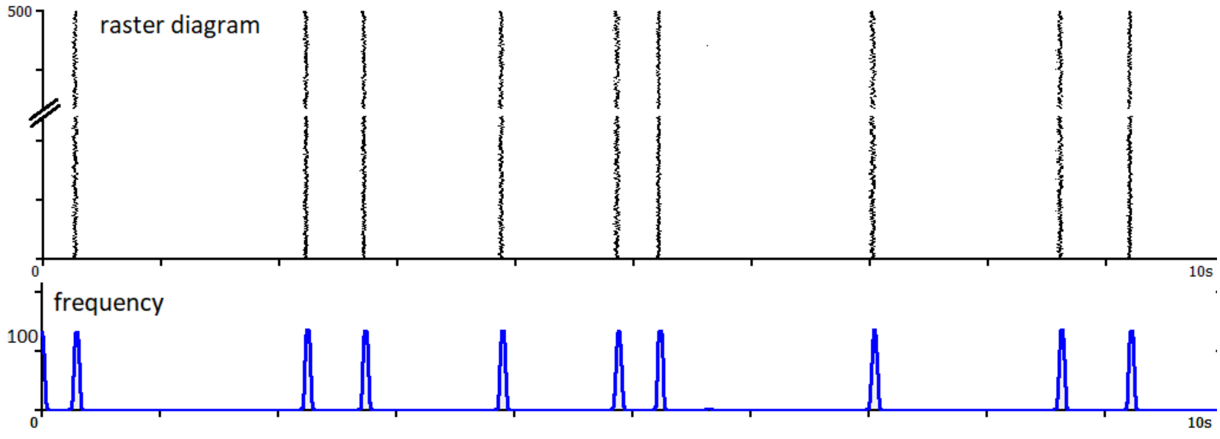
where N_{sp} – the number of spikes of neuron i in the time window t = 50 ms. Further, the average frequency of the spikes in the network is calculated as the arithmetic mean of the frequencies of all N_n neurons:

$$\bar{f} = \frac{\sum_{i=1}^{N_n} f_i}{N_n}.$$

4. **Burst frequency** – spike burst frequency. Network bursts in the program are detected by the peaks of the average spike frequency curve in the network with a threshold value of 5 Hz. That is, if there is a peak on the graph of the average frequency of spikes in the network, the amplitude of which is more than 5 Hz, the set of spikes that caused this peak is classified as a burst. Accordingly, the burst frequency is the frequency of network bursts:

$$f_b = \frac{N_b}{t_b},$$

where N_b – number of population burst in the time window t_b = 5 s.

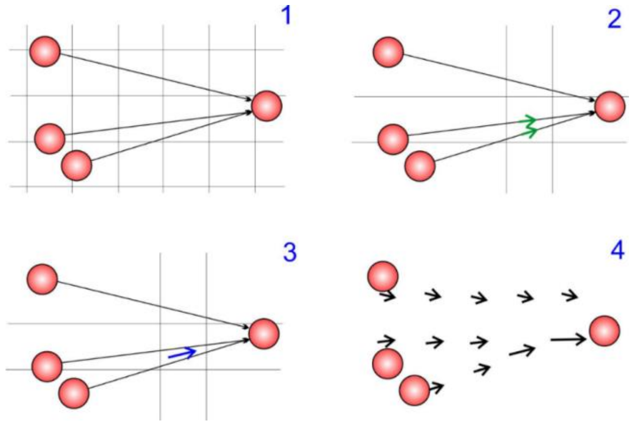


Weights vectors

Neuronet uses a vector field of weights to visualize the structural features of a network. The field construction algorithm includes the following steps:

(1) the area occupied by the simulated neural network is represented as a grid;

(2) each synaptic connection is associated with a vector (green arrow in Fig. 2), the direction of which coincides with the vector connecting the neurons, and the length is equal to the synaptic weight of the connection;



(3) for each cell, the resulting link vector is calculated (blue arrow). The resulting vector is the vector sum of the vectors described in the previous section;

(4) the resulting vectors of all cells (black arrows) are displayed on the network map.

The vector field of connection weights, generalizing information on a large number of synapses, shows the direction of "strong" connections. The figure shows an example of visualization of three connections between neurons in the form of a vector field. In this case, all links have the same maximum weight equal to 1, and the difference in the length of the vectors is due to the different number of links per cell.

To display the weights vector field, choose **View→ Show weights vectors** from the menu.