Introduction

These tutorials will provide you with a practical introduction to using the neural simulation software and give you an insight into the principles of connectionist modeling. They are intended to be complementary to the detailed operation manual. Detailed instructions on which buttons to press are not included here in most cases.

Links

- iqr page: http://iqr.sourceforge.net
- repository of iqr packages (http://sourceforge.net/project/showfiles.php?group_id=190531)

Bugs and features on sourceforge

- Submit bug report (http://sourceforge.net/tracker/?group_id=190531&atid=933732)
- Submit feature request (http://sourceforge.net/tracker/?group_id=190531&atid=933735)

Code on sourceforge

- browse SVN repository (http://sourceforge.net/svn/?group_id=190531)

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Tutorial 1: Creating a simulation

Aims

- Understand and assimilate the basic **principles** and **concepts** of iqr:
  - System
  - Process
  - Group & its properties (neuron type, topology)
  - Random Spike Neuron & properties (probability, amplitude)
  - Cycles Per Second (CPS)
  - Space plot, Time plot & Sync plots
- Create a simulation containing a group of cells that spike randomly
- Run the simulation and see the output using Space Plots and Time Plots.
- Build your first iqr system

Advices

- Go slowly.
- It is important that you ***understand*** what you are doing. Try to assimilate the concepts (group of neurons, process, synapses, time plot, CPS, arborization, etc) when their appear. Otherwise you will be lost for future exercises.
- Keep a copy of the "***iqr User Manual***" handy, and make sure you read the corresponding section in the manual when new concepts are introduced. Checking each concept there will save a lot of time.
- It is also important that after the practicum you create back-ups of every file.
- Don't forget to save your simulation after you make modifications:
  - File → Save As and give it a name like **Tutorial 1**.

Introduction

iqr is is a tool for creating and running simulations of large-scale neural networks. The key features are: graphical interface for designing neuronal models, graphical on-line control of the simulation, change of model parameters at run-time, on-line visualization and analysis of data, the possibility to connect neural models to real world devices such as cameras, mobile robots, etc; predefined interfaces to robots, cameras, and other hardware, open architecture for writing own neuron, synapse types, and interfaces to hardware.

Models in iqr are organized in different levels: the top level is the ***system*** and contains an arbitrary number of ***processes*** and ***connections***. Processes in turn consist of an arbitrary number of ***groups***.

At the process level it can be defined if a process is a standard process or if it connects the system to external hardware. Each process works as a logical unit in which groups of neurons can be defined. Such a logical unit is responsible for a specific task at your system.

A **group** is defined as a specific ***aggregation of neurons*** of identical type, specific in terms of the *topology* (i.e. spatial arrangement) *of the neurons* in the group being a ***property*** of the group.

Connections are used to feed information from group to group. A connection is defined as an ***aggregation of synapses*** of identical type, plus the definition of the arrangement of the synapses.

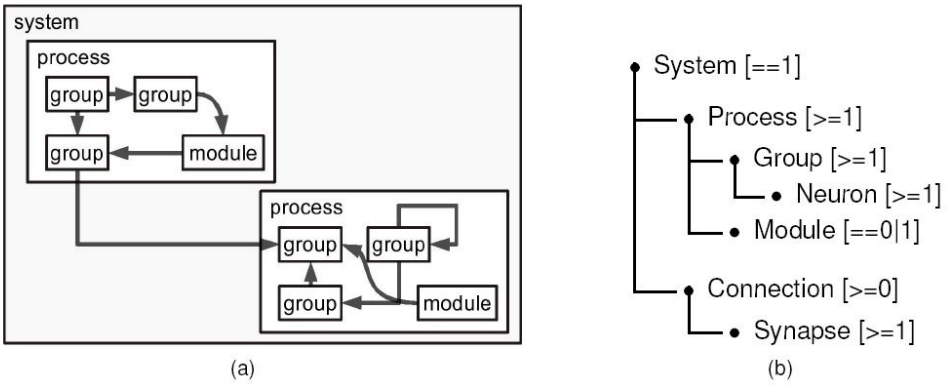

Fig. 1: IQR basic conceptual schemes

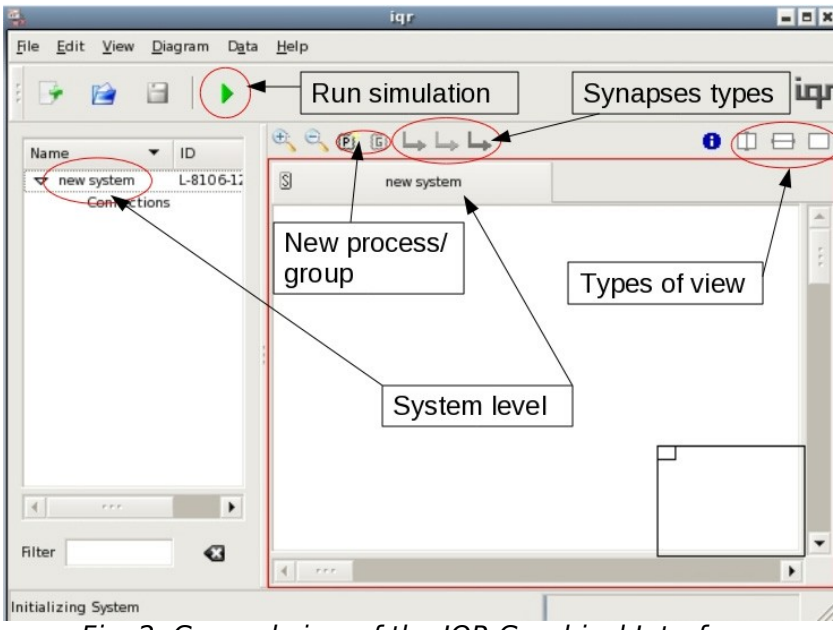

Fig. 2: General view of the IQR Graphical Interface

Building the System

- First of all, you have to create a **process** using the *process button* in the button bar. This will happen at the **system level** (*New System* in Fig. 1). To do this, press the process ('*P*') button and then move the mouse to the "diagram editing panel" and press left button again. A grey square '*New Process 1*' should have been created (Fig. 3).
- Once the process is created, you edit its name by editing its properties. Change the name to ***"Tut 1 Process"***. A new **tab** appears when the process is created. If you click on it, it shows the contents of that process (i.e.: groups and connections) as shown in Fig. 4.
- Click the *"Tut 1 Process"* tab. Start adding groups that will performance inside the process by clicking on the *group icon.*
- Now edit the properties of the new group and set:
  - Set '***Group Name***' as 'RandomSpikeGroup'.
  - Set the *type* of the ***Topology*** as 'TopologyRect' and click there '*edit*'. Make it 10 cells wide and 10 cells high (it will be used again in later exercises). Note: *Topology* refers to the packing of the cells within the group. In this case *TopologyRect* means that every field in the lattice is occupied by one neuron.

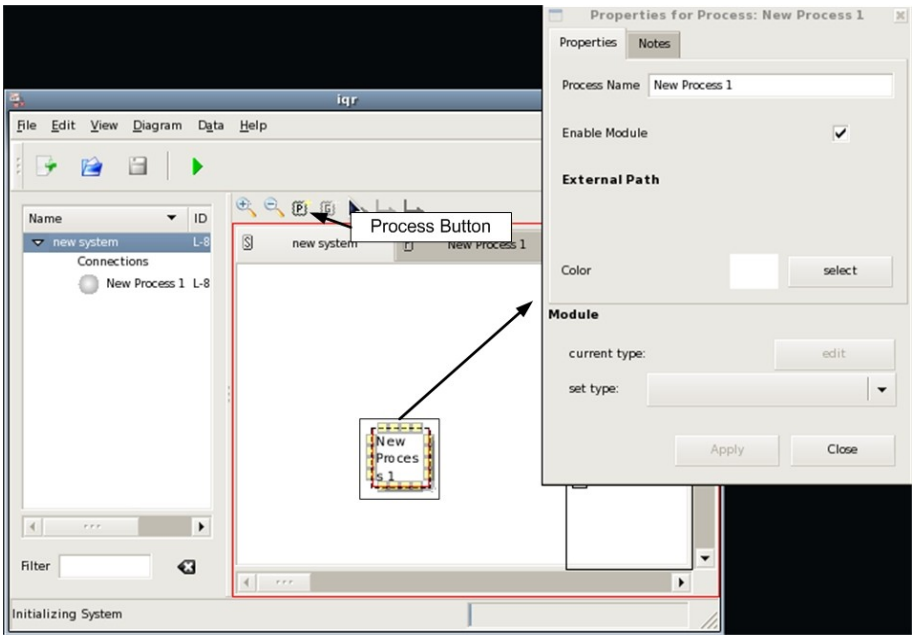

Fig. 3: Process creation and process properties

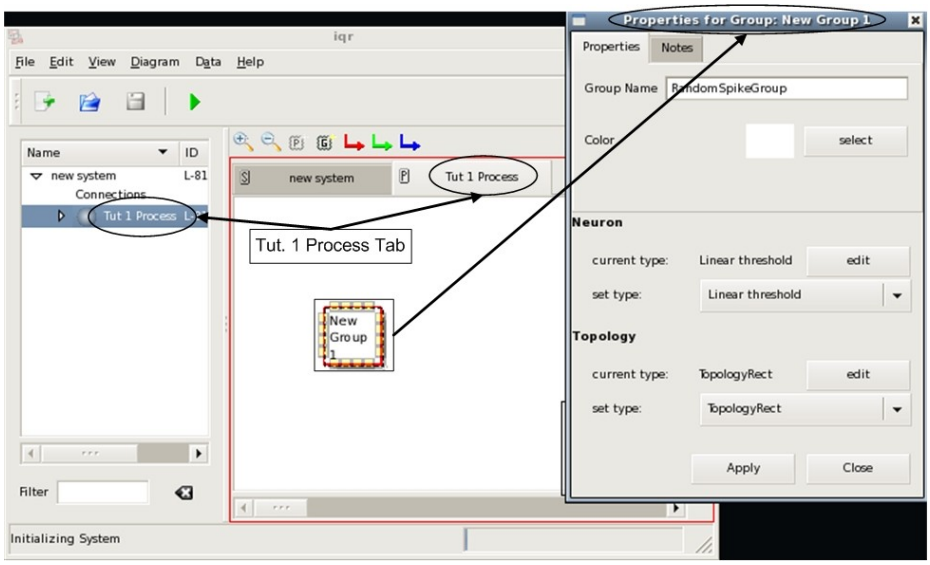

Fig. 4: Group creation inside a process and group properties

- Set the '***Neuron type***', the **type** of the neuron, to **RandomSpike.** Then press *edit* and give it a ***spiking* '*Probability*'** of 0.42 and set the '***Spike Amplitude***' to 1.0.

Exercise

Step 1. Set ***cycles per second*** (CPS) to 25:

- Go to File → System Properties. Set 'Cycles Per Second' (CPS) to 25. Press 'tab' key and then OK. (CHECK: open again the same menu to make sure CPS is set as you wanted.).
- Check also 'Sync Plots' to make sure every event is represented in real-time in the space and time plots.

Step 2. Press the *Play button* to start the simulation.

1. Press right button over the neuron group, and bring up the **space plot** to watch the cells spiking - don't forget to select the '***live data***' check box and choose the *cell state variable* that you want to watch (***activity*** means only when the cell spikes). In brief, the space plot shows the state of each cell in a group in the plot area.

    Q1. What do you see? Which is state is being represented? Is it similar to the bottom diagram in Fig. 5?

    Q2. What does each small square represent?

    Q3. Can you see activity of two different times in space plot or it is just instantaneous information?

2. Press right button again over the neuron group (without quitting the space plot) and bring up a **time Plot** as well. Check again '***live data***' and the same cell state variable as the space Plot. In brief, time plot shows the states of neurons against time.

    Q1. Explain what you see.

    Q2. Are you watching in the time plot the activity of one neuron, the average of the whole group of the total activity of the whole group?

3. Try to play with the properties of the neuron group (such as Probability, Spike Amplitude and Size of the Group). STOP the simulation before changing those parameters.

    Q1. What does that 'Probability' means?

    Q2. What happens if you set probability to '1'?

    Q3. What happens in the space plot if you change spike amplitude? And in the time plot?

    Q4. What about the size of the group? Describe the effects in both type of diagrams.

    Q5. Can you perceive any substantial difference in the space plot?

4. Now, drag only 1 cell from the space plot in the time plot.

    Q1. What do you see?

Q2. What about dragging a group of 4 cells for example?

Q3. Does it give you the sum of the individual activities of the average of the selected group? Play with different combination of cells to discover it.

5. What does the "CPS:" in the bottom-left corner of the window mean? Change the values in File → System Properties and check how the simulation speed changes (e.g.: CPS = 1; CPS = 2; CPS = 10. Take care because CPS=0 gives you the maximum speed the machine can give and it might freeze the system).

Q1. What is a CYCLE in IQR?

Q2. Can you see different cycles at the same time in a space Plot?

Q3. Can you see different cycles at the same time in a time Plot?

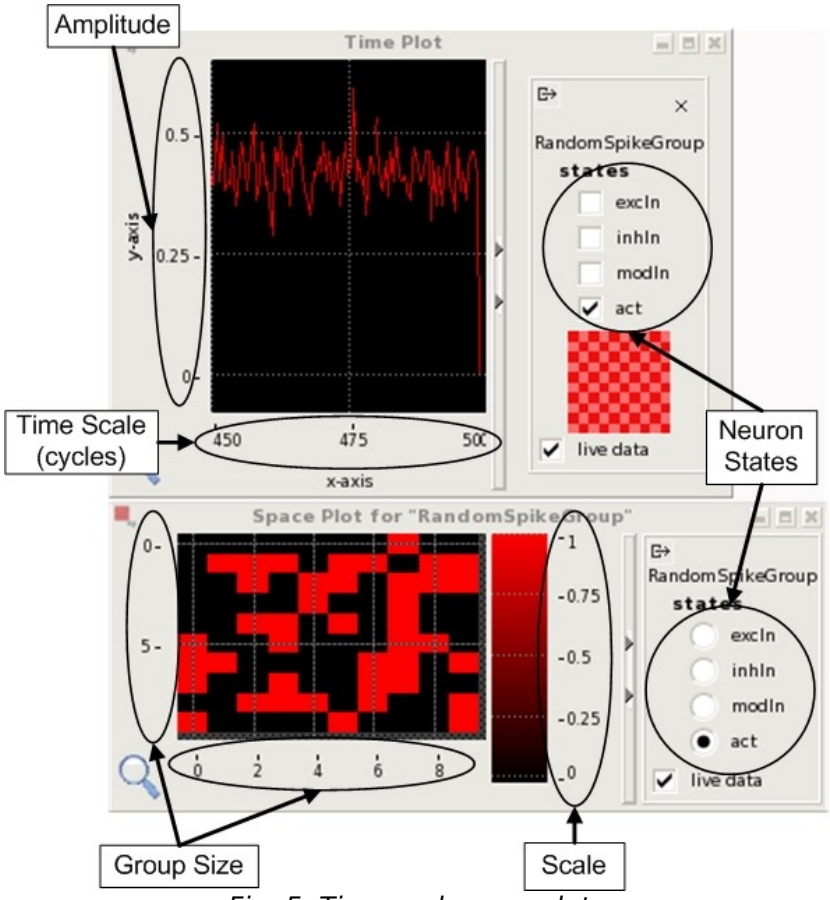

Fig. 5: Time and space plots

Tutorial 2: Cell Types, Synapses & Run-time State Manipulation

Aims

- Understand and assimilate the basic principles and concepts of iqr:
  - Neuron groups: Random spike, Linear threshold, Sigmoid, Integrate and Fire.
  - Neuron properties: threshold, excitatory gain, membrane persistence.
- Link multiple cell groups of different types using connections:
  - Synapses & connection properties (synapse type: 'uniform fixed weight', pattern map).
  - Connection plot

Introduction

In iqr models, the main difference between types of neurons (for mathematical formalization, please refer to the iqr manual) is the **transfer-function** between the inputs and the outputs, and how the inputs are integrated in the membrane potential.

- **Linear threshold (LT):** it sums up all the inputs with a certain gain *(excitatory* gain for excitatory connections or *inhibitory gain* for inhibitory connections). Then, there is a **threshold**. Once the integration of the inputs (what constitutes the *membrane potential*) is over the threshold, the output follows **linearly** the input, otherwise output is zero. The integration of the inputs can be also manipulated by a parameter called **persistence**. This parameter determines how much of the Membrane Potential in time *t* still remains in time *t+1*. This allows a neuron to integrate signals over time, not only instantaneously, therefore providing some sort of memory.
- **Integrate and Fire (IF):** it works very similar to LT neuron, but there is a big difference when the membrane potential reaches the threshold: the IF neuron spikes with maximum amplitude (usually is 1), independently of the input, and then resets the membrane potential to 0. Again, it is possible to use the membrane persistence to allow faster spiking activity.
- **Sigmoid (S):** In this case the transfer function is a sigmoid and there is not possible threshold to set. Persistence does matter again.

Building the System

Open the simulation you created in Tutorial 1. Then create a copy: to do this is use File → Save System As option in the main menu. Give it a name like 'Tutorial 2'. Change also the name of the process to something like 'Tut 2 process'.

Change the spiking probability of your original "*RandomSpike*" cell group slightly, e.g. to 0.1 (the exact number does not matter).

Create three more neuron groups of 1 single neuron. The types for these new groups must be: a *linear threshold*, an *integrate and fire* and a *Sigmoid*.

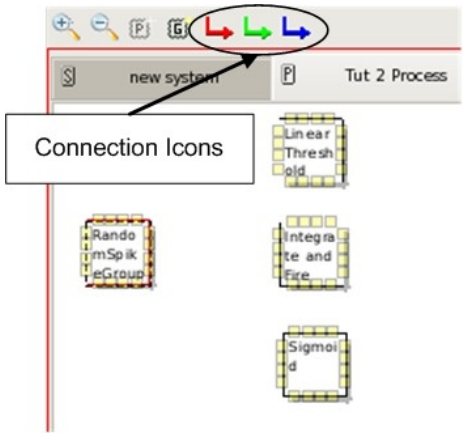

Fig. 6: Connection Icons

Now create excitatory connections from the RandomSpike cell group to each of your new cell groups, using the red connection creation button that appears in Fig. 6. The result of the connection scheme is in Fig. 7.

Every red line represents a connection. Click right button over one of them and choose properties:

- Change the **synapse type** (it appears at the bottom of the Fig. 7) for each connection to ***Uniform fixed weight***. This means that the weight does not change during the simulation and it will be fixed to certain value (if it is set to '1', it means there is no gain or loose of potential during the connection).
- Set the **pattern map** to **“all”** instead of “**center”**.
- Once you have changed that, press *Apply* and *Accept*. If apply is not pressed changes will not be stored.
- Click right button in the connection and select **connection plot**. It gives you a the idea of how each neuron is connected to the other one. This is a useful tool that you may want to use every time you create a new connection to check if the mapping you want is correctly set.

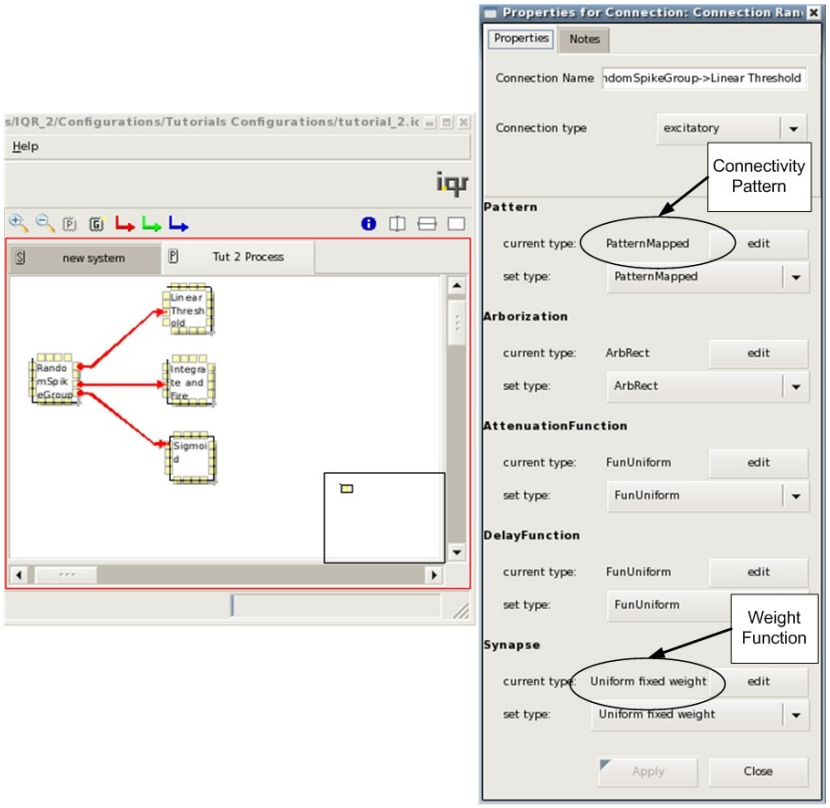

Fig. 7: Excitatory connection scheme and Connection properties dialog

- Play with it. Click in both 'squares' that represent the neuron groups. Arrow shows the 'source' (origin of the arrow), and the 'target' (arrow end) of the connection. This means that one spike in a neuron (or group of neurons) of the source is propagated through the connection to another neuron (or group of neurons) of the target, making them to spike (according to the neuron transfer function, threshold, etc). Best thing is to create bigger groups of neurons and define different patterns to check this tool.

Exercise

1. Bring up space and time plots for each cell group and start the simulation. Every one has the name of the group, so check if you can identify each one. What do you see?

   A. Connection between Random Spike (RS) and Linear Threshold (LT) groups.

      Q1. Space plot: is the cell spiking continuously?

      Q2. Time plot: is it following the source? Why? (Note: think of the pattern map and also in the definition of LT neuron.)

   B. Connection between RS and Integrate and Fire (IF) groups.

      Q3. Space plot: why is all the time spiking?

Q4. Time plot: is it following the source? Why?

C. Connection between RS and Sigmoid.

Q5. Space plot: why is all the time spiking?

Q6. Time plot: is it following the source? Why?

2. Inside the **properties** of the neuron groups, play with the **excitatory gain**, **threshold** and **membrane persistence** (check the time and space plots the option '**vm**' that is the membrane potential:

   Q1. Explain what these parameters do:

   Q2. Explain what is the membrane potential and its relation with the input and the threshold.

   Q3. Explain also the role of persistence in the input, the membrane potential and the output.

3. Write down the parameters you have used.

Group name	LinTh	IntFire	Sigmoid
Size (cells)			
Cell Type	Linear threshold	Integrate & Fire	Sigmoid
Excitatory gain			
Probability			----------
Membrane persistence			
Threshold			----------
Membrane potential reset			
Spike amplitude			
Sigmoid midpoint	----------	----------	
Sigmoid slope	----------	----------	

4. Stop the simulation and change the *PatternMapped* to '*center*'. Check again the **connection plot.**

   Q1. Run the simulation watching the plots. What was the effect and why?

   Q2. Play with the size of the neuron groups. One detail to take into account is whether the different sizes are even or odd. Play with this and use the connection plot and change the pattern maps between '*center*' and '*all*' to see what happens.

   Q3. Try to explain what the difference is. Take a look to the manual if you do not know what is going on. Write down a brief explanation.

Tutorial 3: Changing Synapses & Logging Data

Aims

- Understand and assimilate the basic principles and concepts of iqr:
  - Connection type: inhibitory
  - Neuron properties
  - Arborization
- Try out different connection types.
- Manipulate the states of cell groups at run-time and see how the cells are affected.
- Draw some patterns using the state manipulation panel and play them. Save the patterns for future uses.
- Record simulation data for later analysis using the data sampler.

Introduction

1. Arborization

Arborization is a way of having more complex connection between neuron groups. Basically it defines how given a specific connection between two neurons (defined with the *pattern* property), this is extended to the adjacent neurons. There are two options: **receptive field** and **projective field** (Fig. 8).

- *Receptive Field*: a single connection can connect several pre-synaptic neurons to one pot-synaptic neuron.
- *Projective field*: one pre-synaptic neuron projects information over a group of post-synaptic neurons.

You may want to use the *connection plot* when defining arborization to make sure every connection is as you specify.

Hence a connection in iqr can comprise several axons, synapses and dendrites from a biological point of view. In iqr terms, this will be defined as a matrix of connectivity.

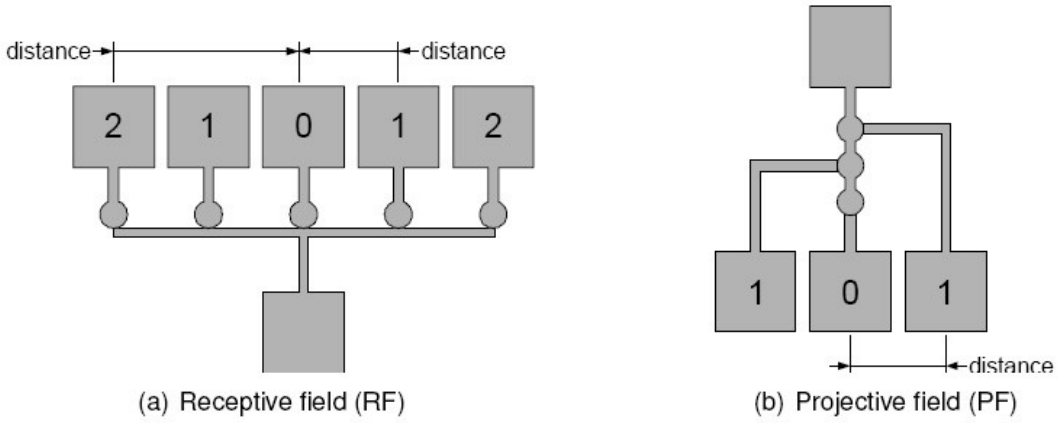

Fig. 8: Receptive field and Projective field in the context or arborization

PLEASE, check the manual for further and deeper explanation and diagrams. (Sec.:2.13.2)

2. Inhibitory connection

In previous chapters we played only with excitatory connections. In this case we will play with the inhibitory type. In this case, the increase of the activity of the pre-synaptic neuron makes a reduction of the membrane potential of the post-synaptic neuron. So if a post-synaptic neuron has two inputs, one inhibitory and one excitatory, the output of the activity of this neuron will be reduced thanks to its inhibitory input. You can also check these types of connections in the *connection plot.*

3. State Manipulation Panel

The state manipulation panel is a tool to manipulate directly the activity of a specific neuron group. The interface is shown in Fig. 9.

PLEASE, check the manual for a complete guide of use.(Sec.:2.16)

4. Data Sampler

Data sampler (Fig. 10) allows you to save data during a simulation. You can save in a text file different parameters of activity (input, output, membrane potential) from the neuron groups you want. This is to log the simulations and to have data in a text format that can be later read and analyzed in other programs like Excel, SPSS, Octave, Matlab, etc. It works very easily just by dragging from the space plots the neurons you want to log into the data sampler interface and selecting the appropriate options.

PLEASE, check the manual for a complete guide of use.(Sec.:2.15.6)

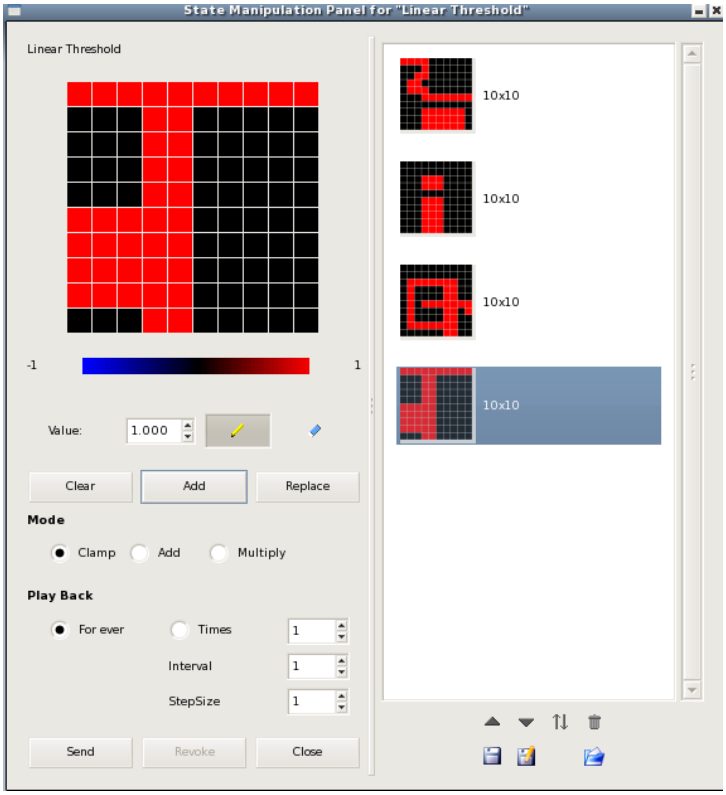

Fig. 9: State manipulation panel

Building the System

- Create a copy of the simulation you used in Tutorial 2 and call it Tutorial 3 and start with it. Rename also the process.
- Delete the Sigmoid neuron group.
- Set the Linear Threshold group properties:
  - Threshold = 0;
  - Membrane Persistence = 0;
- Change the size of the Linear Threshold group using the Topology option to 30 by 30 neurons (if the computer goes slow, reduce it to 10x10 for example).
- Change the size of the Random Spike group to 1 single neuron. Save the simulation when you have finished.

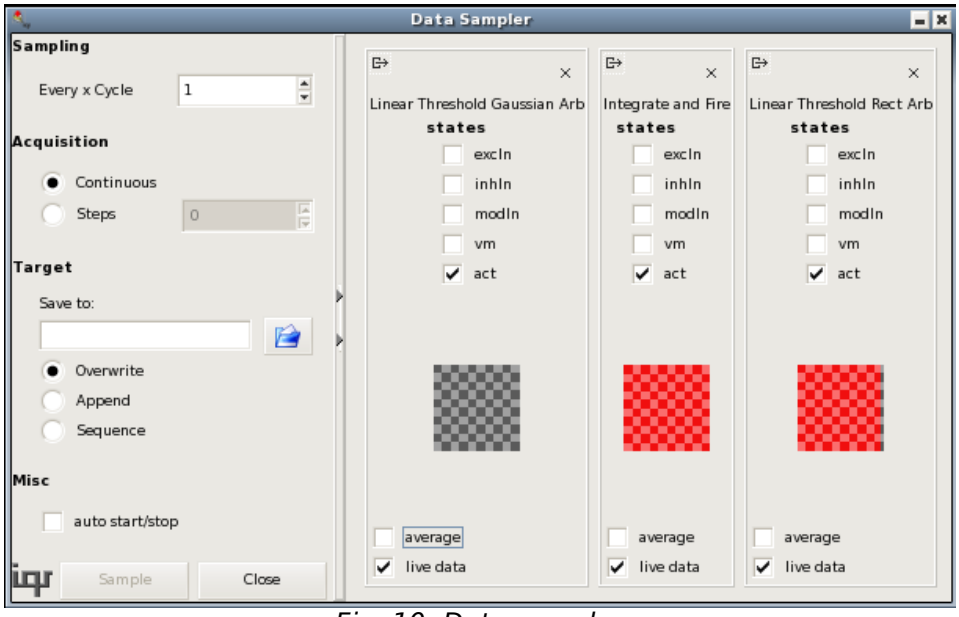

Fig. 10: Data sampler

Exercise

Start the simulation, and bring up the Space Plot and observe the activity in the Linear Threshold group.

1. We want to modify the connection parameters to generate a rectangular, circular and elliptic activation of the post-synaptic neuron group. For that modify the **arborization** properties (Projective Field) and the **attenuation**. In the circular and elliptic case, when using attenuation, you should get space plots similar to Fig. 11. It may be a good idea to check the connection plot to make sure the connection scheme is well set.

   Q1. Write values in the table

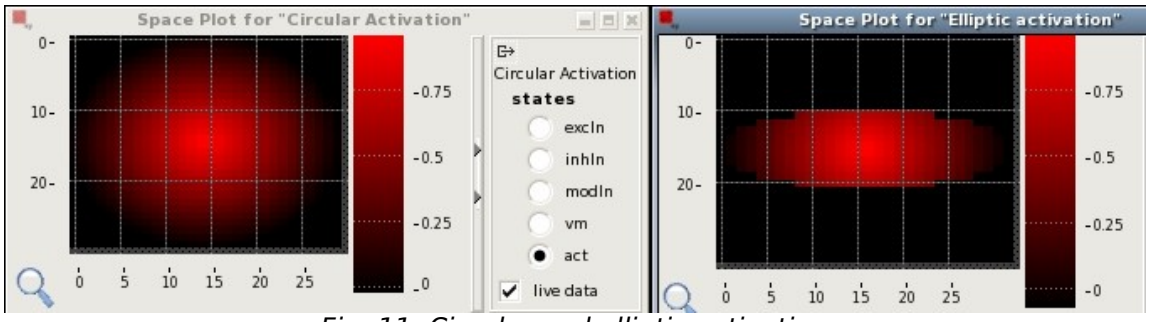

Fig. 11: Circular and elliptic activation

2. Now, repeat the exercise trying to get a Gaussian activation of the post-synaptic neuron group. Again, modify the **arborization** properties (Projective Field) of the synapse and the **attenuation**. You should get a space plot simi-

lar to Fig. 12. The 3-d view of this activation should be similar to Fig. 13.

Q1. Write values in the table

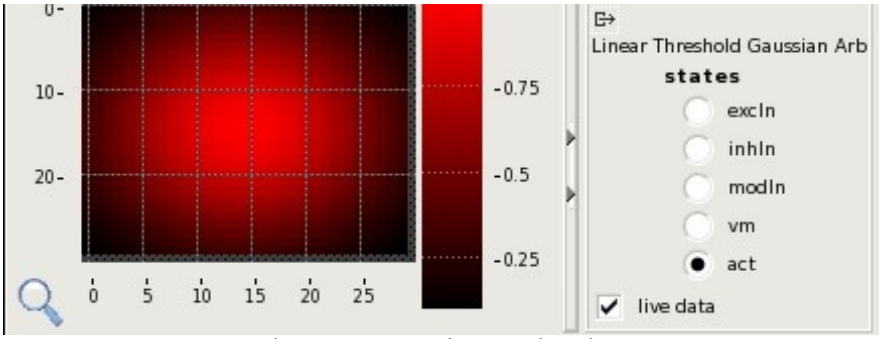

Fig. 12: Gaussian activation

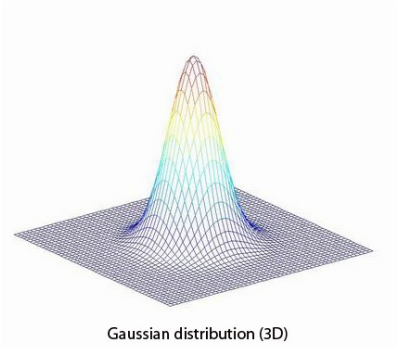

Fig. 13: Example in 3d of a gaussian distribution

Connection	Rectangular	Circular	Elliptic	Gaussian
Pattern				
Arborization				
Attenuation				
Synapse				

3. Stop the simulation. Create an **inhibitory connection** from the Integrate and Fire group to the Linear Threshold one using the blue arrow icon, and set the synapse type to "*Uniform fixed weight*" (this means that every connection between the pre-synaptic neuron group and the post-synaptic neuron has the same weight/gain). Run the simulation again.

   Q1. What do you see?

   Q2. Which is the difference between an excitatory and inhibitory synapse? Check the membrane potential state using the time plot to verify what is happening.

Now we want the Linear Threshold group to have a **receptive field** that respond to surrounding excitation. This means that every post-synaptic neuron must integrate the activity of more than one neuron of the pre-synaptic group. Change the Linear Threshold group dimensions to 1 neuron and the RandomSpike group to 10 by 10.

4. Change also the connection settings to achieve the correct **receptive field**.

   Q1. Which are the new parameters?

Connection	Rectangular	Circular	Gaussian
Pattern			
Arborization			
Attenuation			
Synapse			

5. Use the **state manipulation panel** on the RandomSpike group to generate a *circular, rectangular* and *gaussian* like activation. Bring up the Time Plot of the Linear Threshold group.

   Q1. When is it responding maximally?

6. Open the Data Sampler under the "Data" menu. Save some data from the cell groups of your choice. Open the data file in OpenOffice or Excel.

   Q1. What you see in the file?