Brain Modeling :

A very simple Network model of the Human Brain

By

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Presentation Overview

1. Introduction : Brain, Neuron and Connections
2. Objectives :
3. Model and Implementation
4. First Results
5. A couple of comparisons
6. Conclusion
7. Limitations
8. Futur work

1- Introduction : Brain, Neuron and Connections

- The nervous system is a set of a billion of neurons that communicate with each-other through a billion of billions of synaptic connections. It is apparent to a set of electrical cables connecting nodes, forming a huge network. Most published studies on diseases of the nervous system face the problem of complexity of the nervous system as its whole.

- It is difficult to tell accurately the reason of a dysfunction; this is the case of Autism: Although symptoms of the disease are known, there is no consensus on the reasons of such a phenomenon. Some authors talk about spend energy related to long-distance connections, others talk of poor synchronization between the left hemisphere and the right hemisphere, others talk about poor quality of the gray matter, namely, the myelination of axons, key for inter-regional communication, … Those are known through Infra-red and a bunch of scanning tools.

- It is very hard for Biologists to figure out what is really going on. We then need model with which we can manipulate different possibilities and observe the results.

2- Objectives

- Multi data processing with network implementation in order to mimick the Humain Brain, and try to identify potential reason for dysfunctions like Autism, Alzheimer, Parkingson, …

- Build 2 X 3D networks with as much as neuron possible
  (Abnormal Network → Dysfunction Vs Normal Network → Safe).

- Analysing :
  - Simple Correlations between parameters such as ATP and length all along the signal processing.
  - How does a specific parameters change between those 2 Networks can make a difference
  - … (if time allows)

3-Model and Implementation

A) Model

- I choose not to use in a first step the huge and enormous equations that rules neurons input and signal transfer we may see in the literature, in Electrical and physics. Instead, I used the simplified model of neuro-psychology, which is easier to implement. However, those equations in Electrical can be included in the model.

- Action Potential that decide whether a Neurone fires or not is not based on Boolean value but based on both time and neurotransmitter abundance.

  $\sum$ (neurotrans X action) = received inpulse

  if received impulse >= Threshold then –> Fire

- I consider the time in the entire Network, and this time is based on the time recorded at signal input (button press).

3-Model and Implementation

A) Model

- I started with 64 neurons in the Network (just to avoid long time running more than 1000 Neurons which is the final goal for now).
- I have 1 Main_File that store the information on all Neurons (ID, myelinated or not, strength of myelin, if it is an Activator, if it is an Inhibitor, coordinates X, Y, Z in 3D space, Action_Potential_Threshold).
- I designed a graphical interface that allows to directely Update that File (In a random way, and also in specific way : Ex: one can choose how one want the Neuron_X to behave with its neighboor).
- I have 64 Files That store each Neuron interaction (1 File per Neuron).
- With the graphical interface, one can directly update the behavior of any Neuron with its Neighboors. Then, there is 2 ways to update :
  - ✓ Either by area (you update interactions of neurons located in the selected area : the best choice for general analysis).
  - ✓ Either by ID (you update interactions of neurons taping is ID: this would be the best choice for very-very deep analyse, but extremely long to do with 1 million neurons).
- Regarding Neuron Interactions: it is information such as : Neighboors (consequentelly I have 64 lines), behave = Activation or Inhibition or Nothing (this depend on the previous Main_file), Strenght of that interaction, duration of signal transmission, length with the Neighboor, ATP spent while the signal is travelling, Current time of signal perception.

- In the next slide, all stuff put in color are not random; They depend on the interaction with the neighboors on the Network.

3-Model and Implementation

A) Model

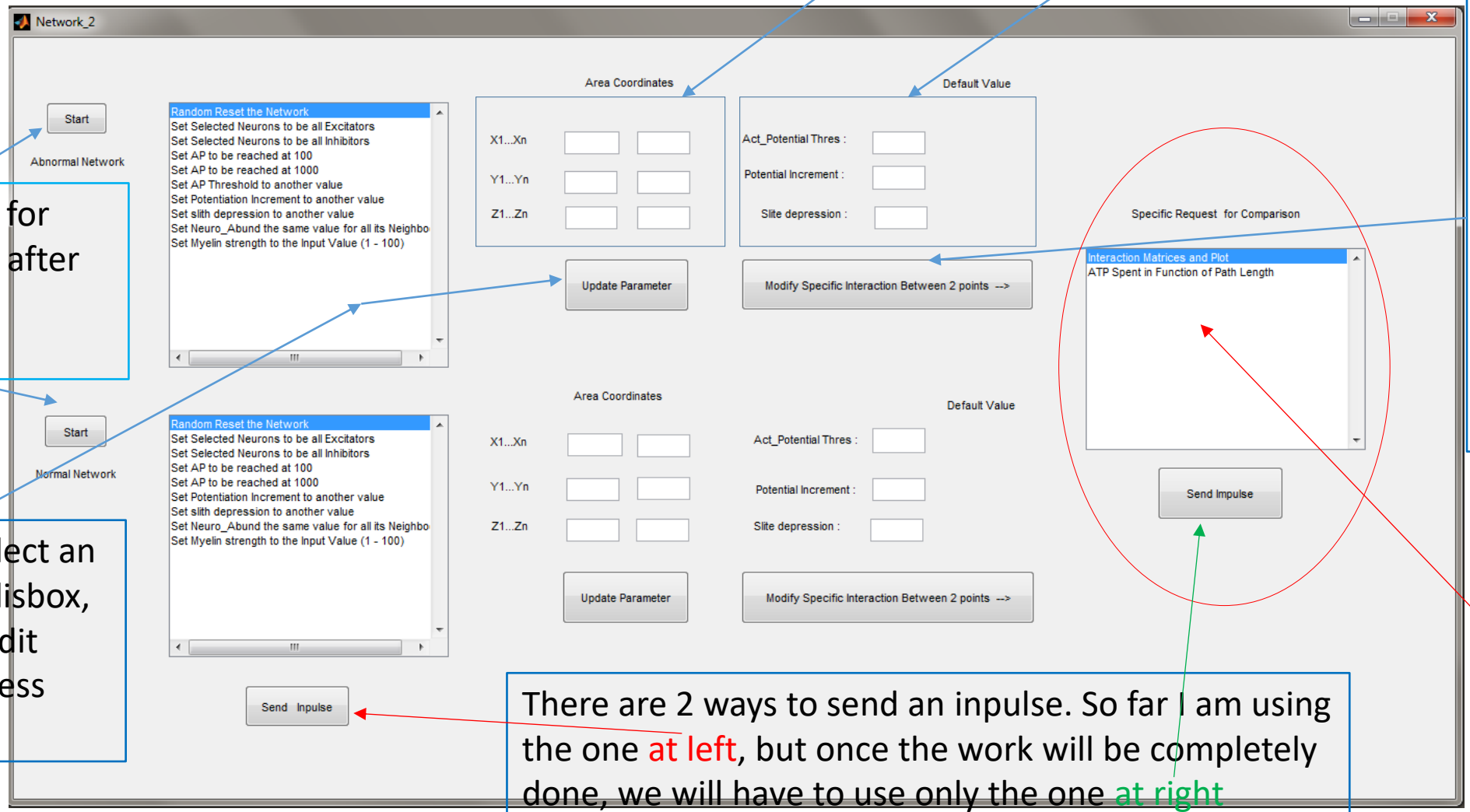
- Activation or Inhibition or Nothing (this depend on the previous Main_file) : When a Neuron is an activator, it is a (+1). When it is a inhibitor, it is a (-1). When He receives a signal, He transfers that signal to its neighboors. Then there is 2 cases : He may transfer a negative signal (inhibitory signal) or a positive signal (activator signal).
- If He transfers a positive signal, and that neighboor fires, that firing strengthens their relationship ; in case of non-firing, it diminish their relationship
- If He transfers a negative signal, and that neighboor fires, that firing diminishes their relationship ; in case of non-firing, it strengthen their relationship.
- Strength of that interaction : Dependent on quantity of neurotransmittor.
- Duration of signal transmission : depends on both distance between 2 neurons, and the force of the Myelin layer; The longer is the distance, the longer it takes the signal to travel. The thicker is the myelin layer, the faster the signal can travel.
- Length with the Neighboor : It s based on the Cartesian distance between 2 neurons. I added 0 - 10% margin because neural connections are almost never straight.
- ATP spent while the signal is travelling : Inversely proportional to the thickness of the myelin and the length of the axon.
- Current time of signal perception : This allows Matlab to follow the signals. Actually, there are no real signal : those are just timing to follow an imaginary signal through the network.

3-Model and Implementation

B) Implementation : done with Matlab

Edit text allow set-up Action potential Theshold, incrementation Vs decrementation jump

Edit text allows to modify specific areas



This button is to modify a specific interaction between 2 points. It opens a other frame. I will go there in a couple of slides.

Starting point for each network after loading the application

Once you select an item on the lisbox, you fill the edit text, then press update

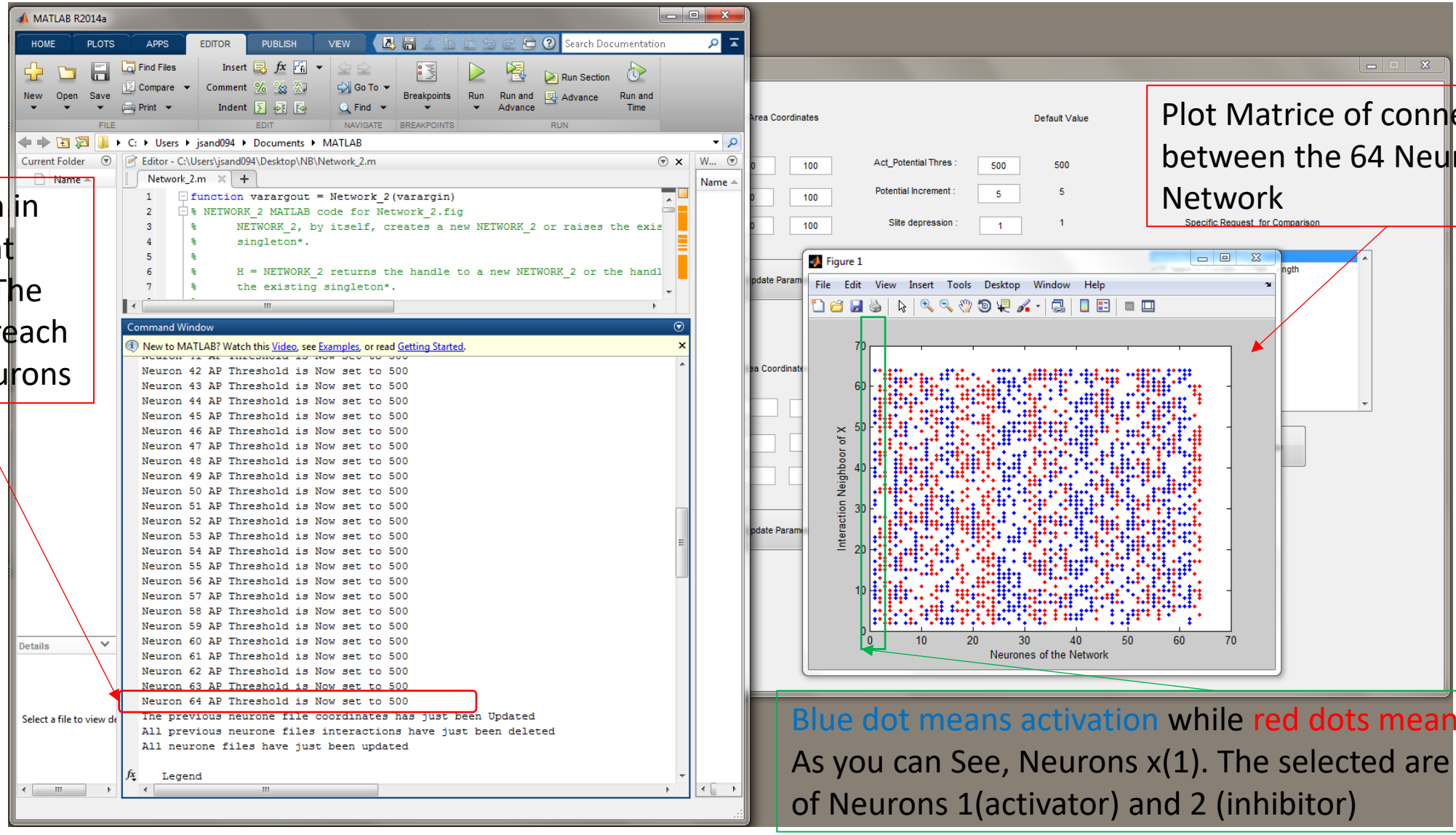
Then selected, it allow me to specify which test I want to perform

There are 2 ways to send an inpulse. So far I am using the one at left, but once the work will be completely done, we will have to use only the one at right

4-First Results

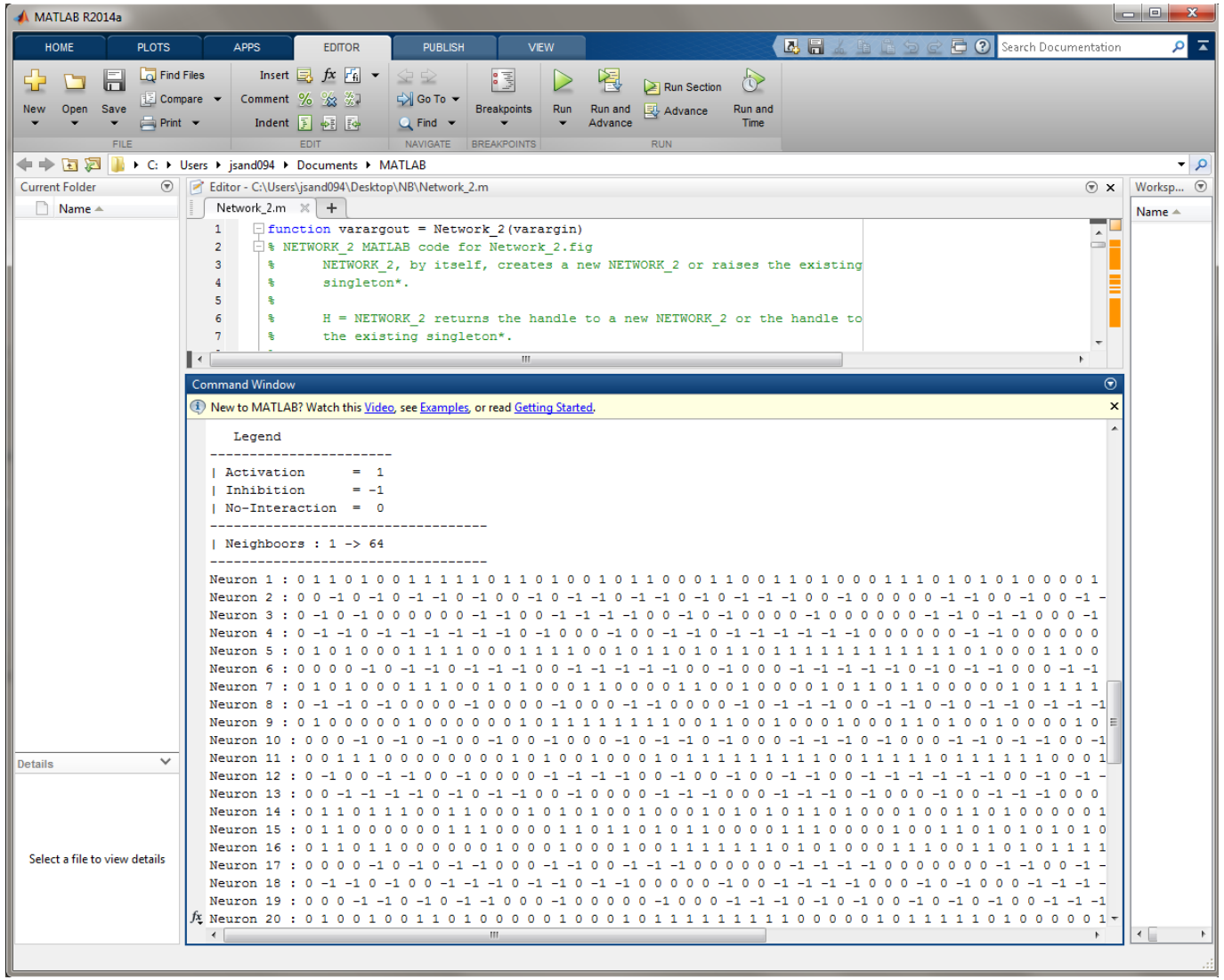
64 Neuron in the current network. The goal is to reach 1000+ Neurons

Plot Matrice of connection between the 64 Neurons of the Network



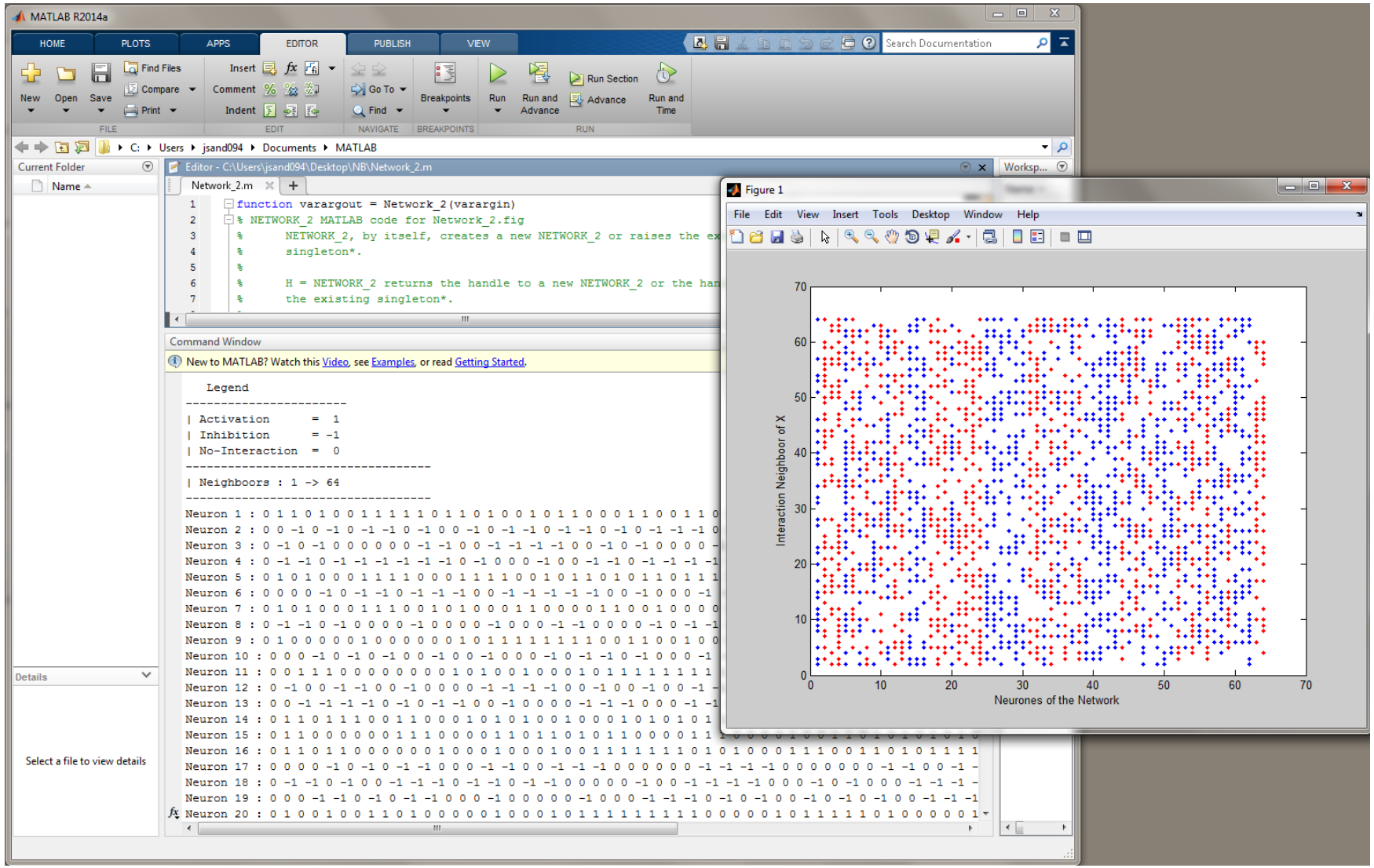
Blue dot means activation while red dots means inhibition. As you can See, Neurons x(1). The selected are neighboors of Neurons 1(activator) and 2 (inhibitor)

4-First Results



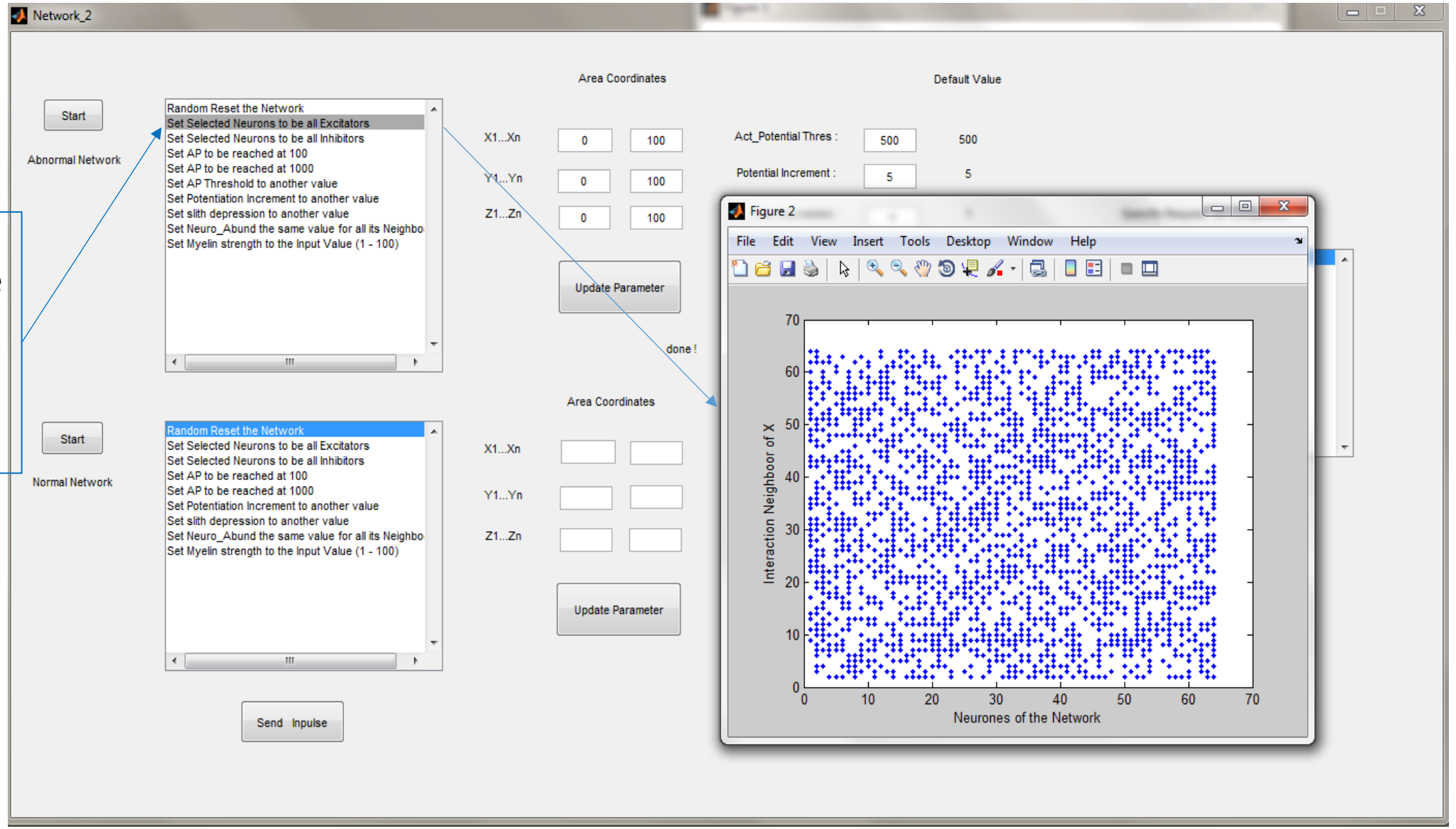
Another view of the Connection Matrice

4-First Results

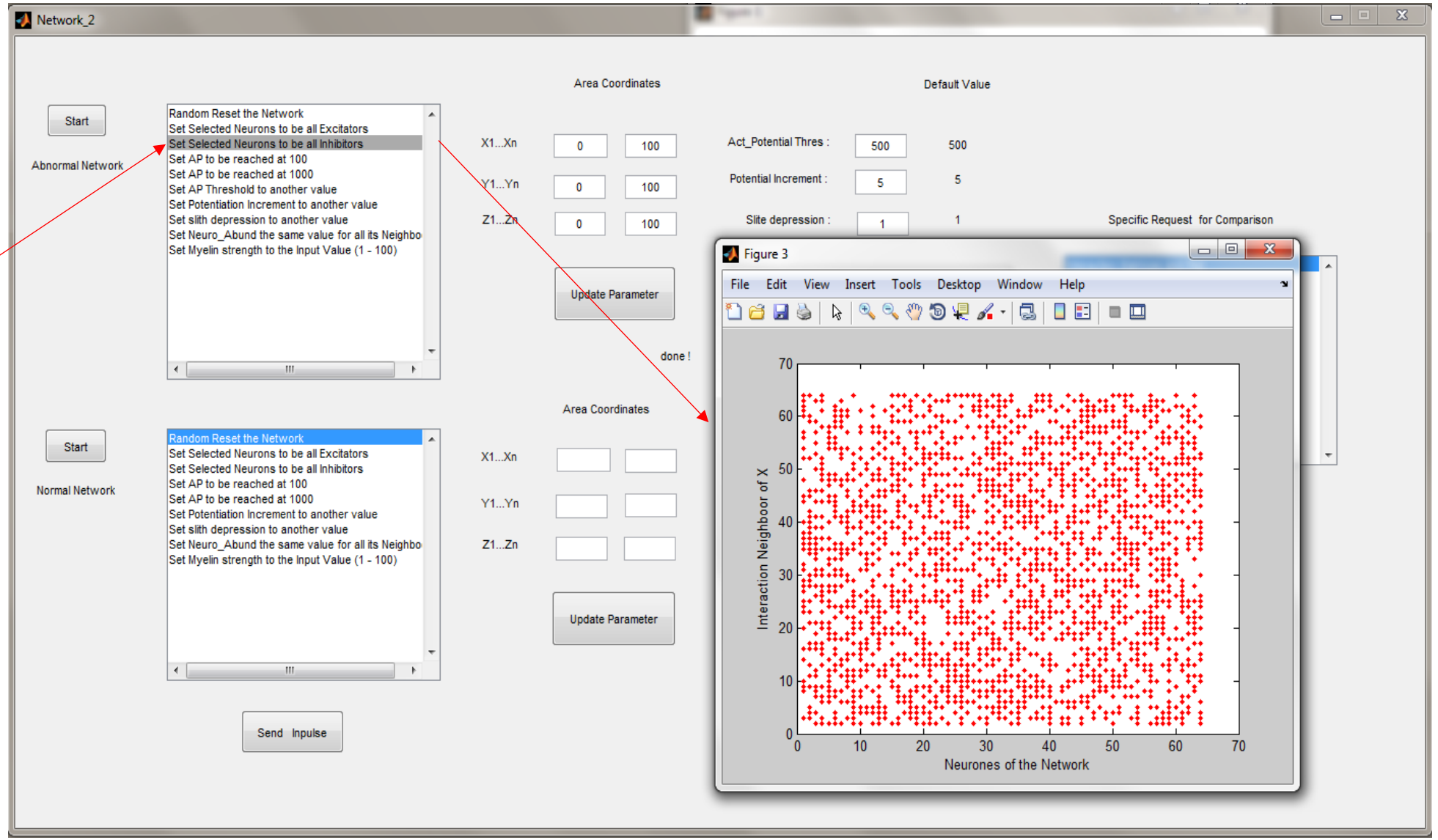


4-First Results

Let s set all Neurons to be Excitators. Remember, exitators is blue

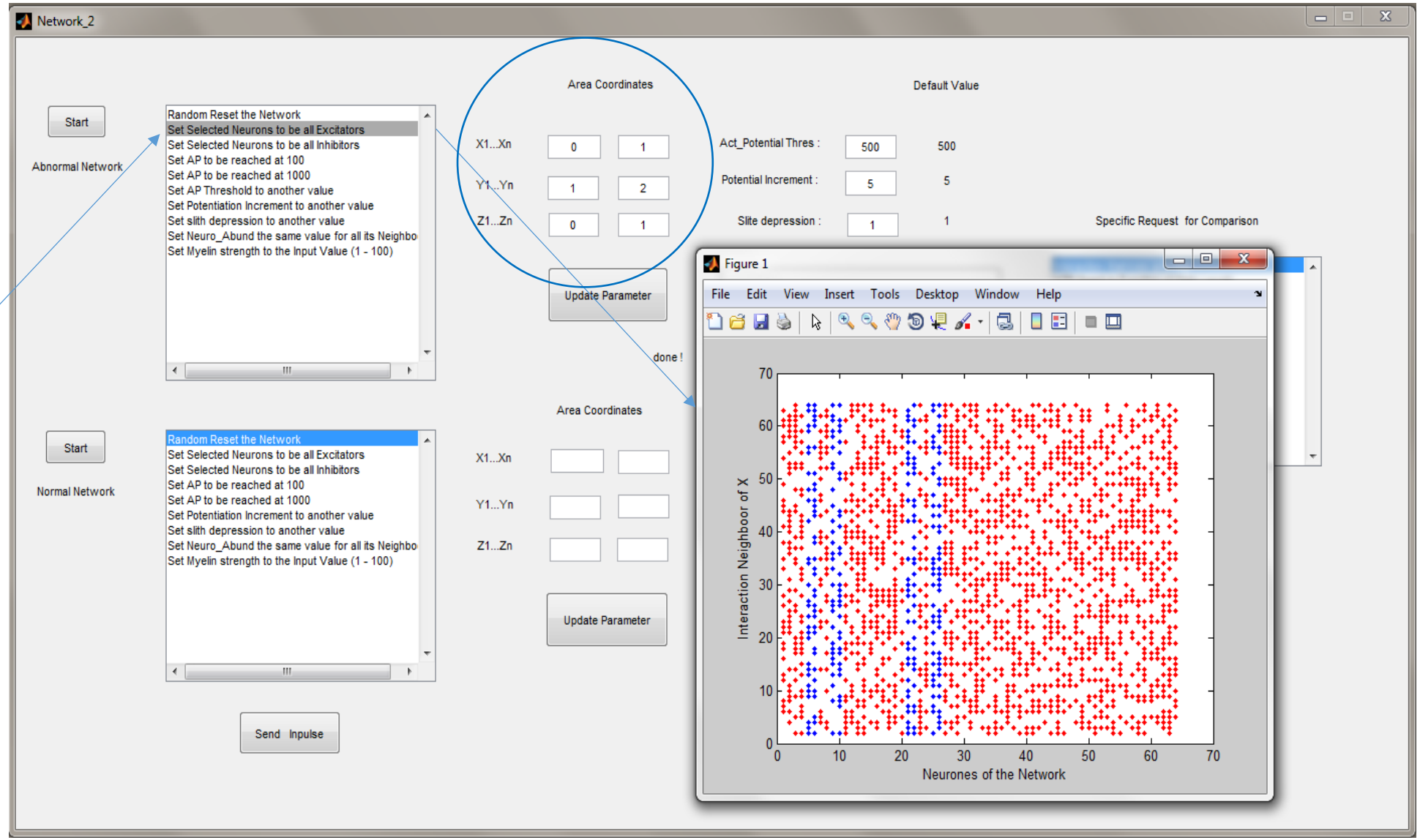


Let s set all neurons to be inhibitors. Remember, inhibitors is red.

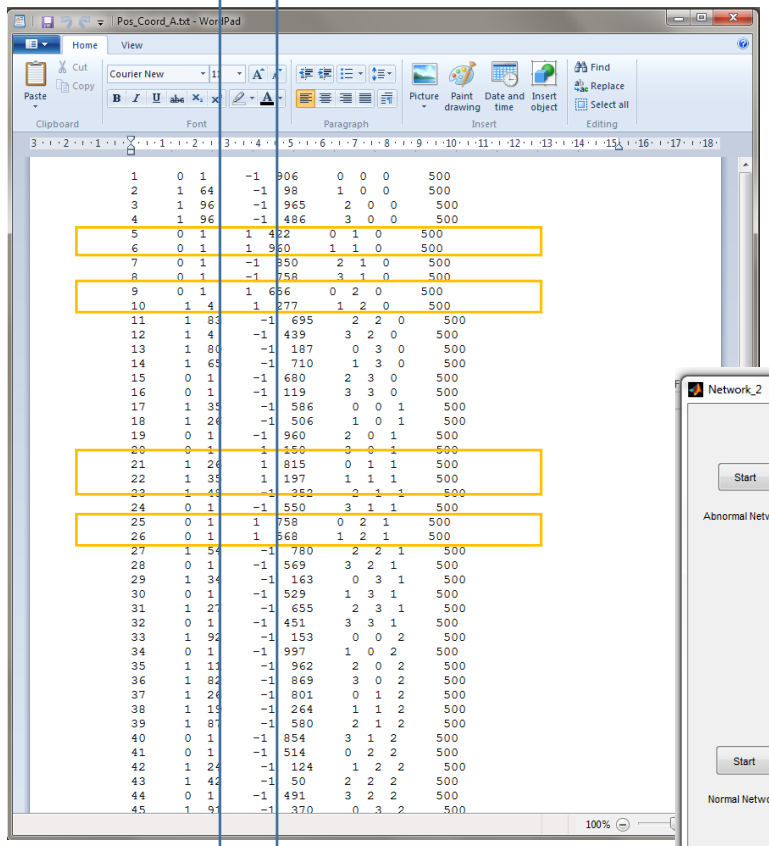


4-First Results

Let select only neurons which coordinates are inside selected Area, to be Excitators.



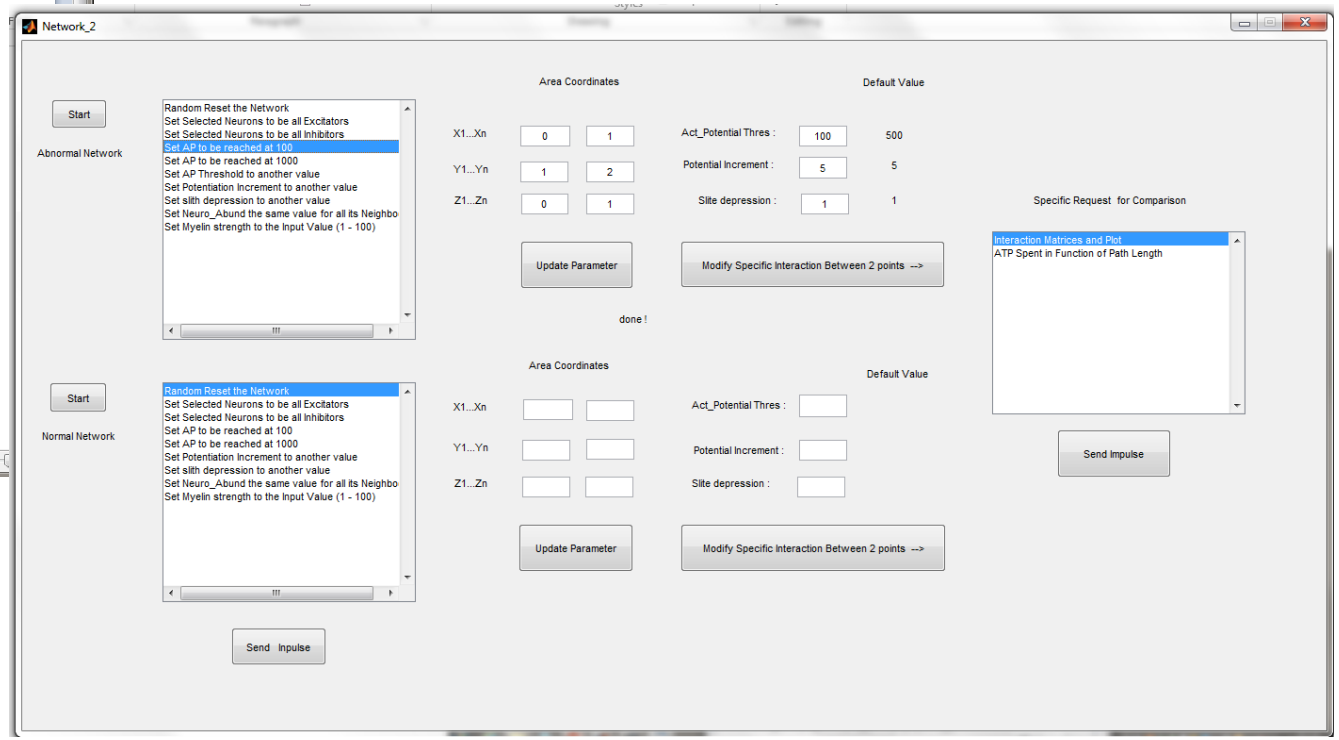
4-First Results



1	0	1	-1	906	0	0	0	500
2	1	64	-1	98	1	0	0	500
3	1	96	-1	965	2	0	0	500
4	1	96	-1	486	3	0	0	500
5	0	1	1	422	0	1	0	500
6	0	1	1	960	1	1	0	500
7	0	1	-1	850	2	1	0	500
8	0	1	-1	758	3	1	0	500
9	0	1	1	656	0	2	0	500
10	1	4	1	277	1	2	0	500
11	1	83	-1	695	2	2	0	500
12	1	4	-1	439	3	2	0	500
13	1	80	-1	187	0	3	0	500
14	1	65	-1	710	1	3	0	500
15	0	1	-1	680	2	3	0	500
16	0	1	-1	119	3	3	0	500
17	1	35	-1	586	0	0	1	500
18	1	26	-1	506	1	0	1	500
19	0	1	-1	960	2	0	1	500
20	0	1	1	150	3	0	1	500
21	1	26	1	815	0	1	1	500
22	1	35	1	197	1	1	1	500
23	1	48	-1	352	2	1	1	500
24	0	1	-1	550	3	1	1	500
25	0	1	1	758	0	2	1	500
26	0	1	1	568	1	2	1	500
27	1	54	-1	780	2	2	1	500
28	0	1	-1	569	3	2	1	500
29	1	34	-1	163	0	3	1	500
30	0	1	-1	529	1	3	1	500
31	1	27	-1	655	2	3	1	500
32	0	1	-1	451	3	3	1	500
33	1	92	-1	153	0	0	2	500
34	0	1	-1	997	1	0	2	500
35	1	11	-1	962	2	0	2	500
36	1	82	-1	869	3	0	2	500
37	1	26	-1	801	0	1	2	500
38	1	19	-1	264	1	1	2	500
39	1	87	-1	580	2	1	2	500
40	0	1	-1	854	3	1	2	500
41	0	1	-1	514	0	2	2	500
42	1	24	-1	124	1	2	2	500
43	1	42	-1	50	2	2	2	500
44	0	1	-1	491	3	2	2	500
45	1	91	-1	370	0	3	2	500

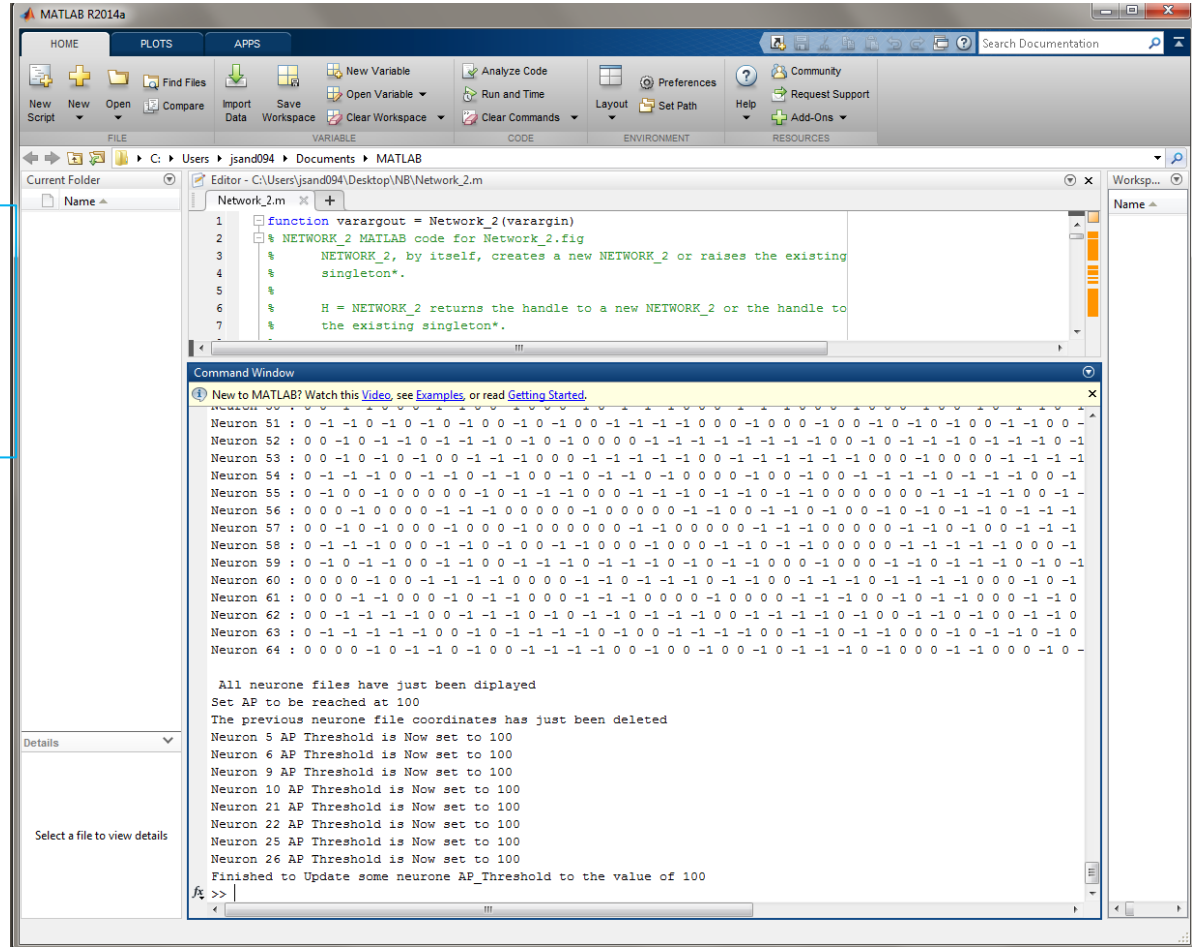
This is the Main_file that stores all initial Neurone information.

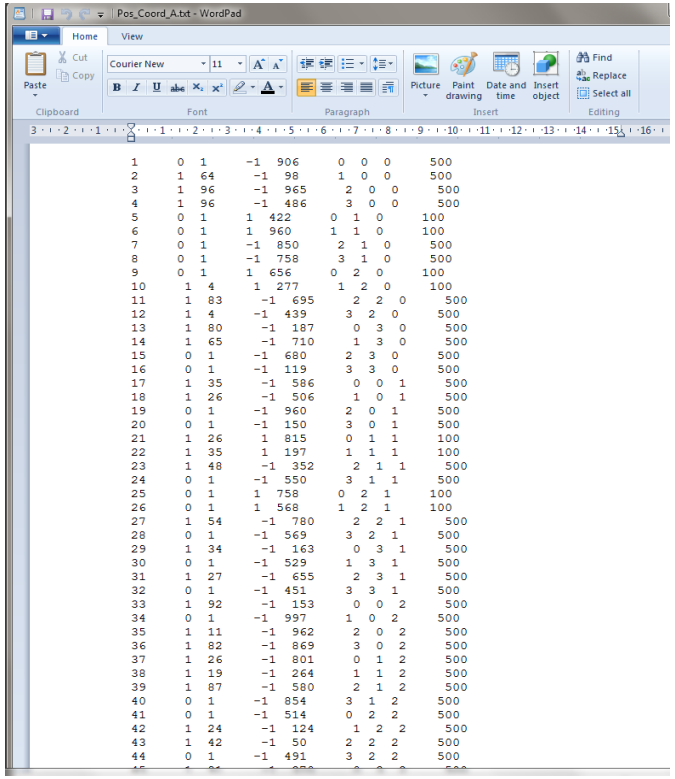
As you can see, we have 8 neurones Excitator (+1) from last set up.



4-First Results

Set selected Neurons Action Potential to be reached at 100 neuro-transmitors.

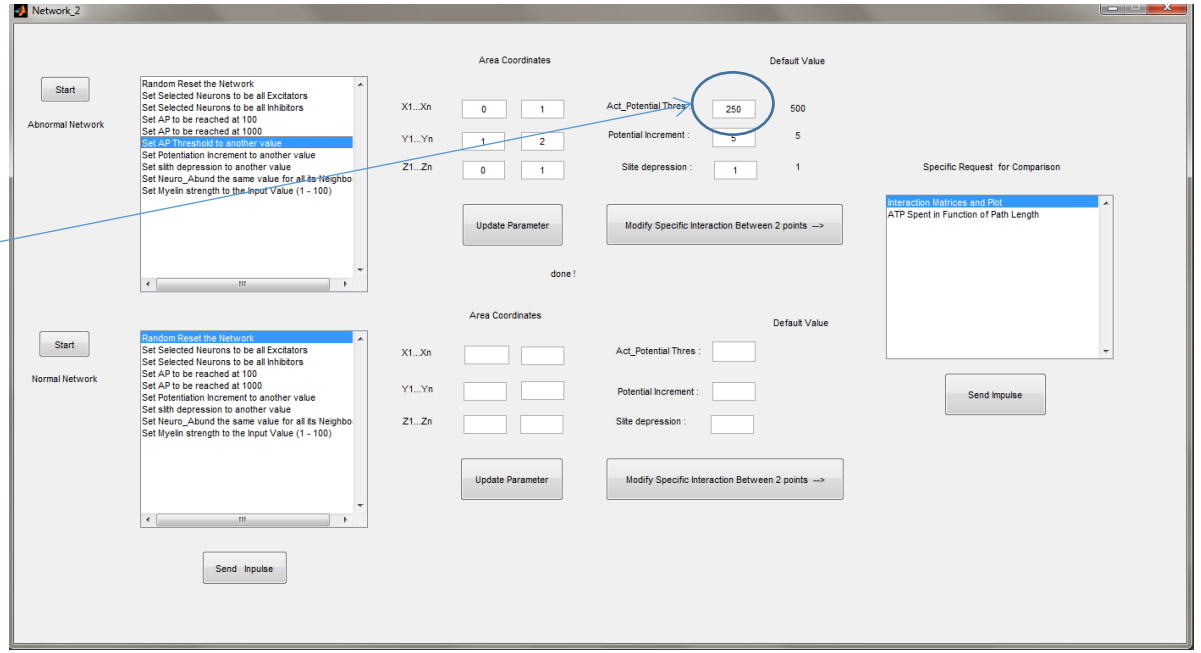




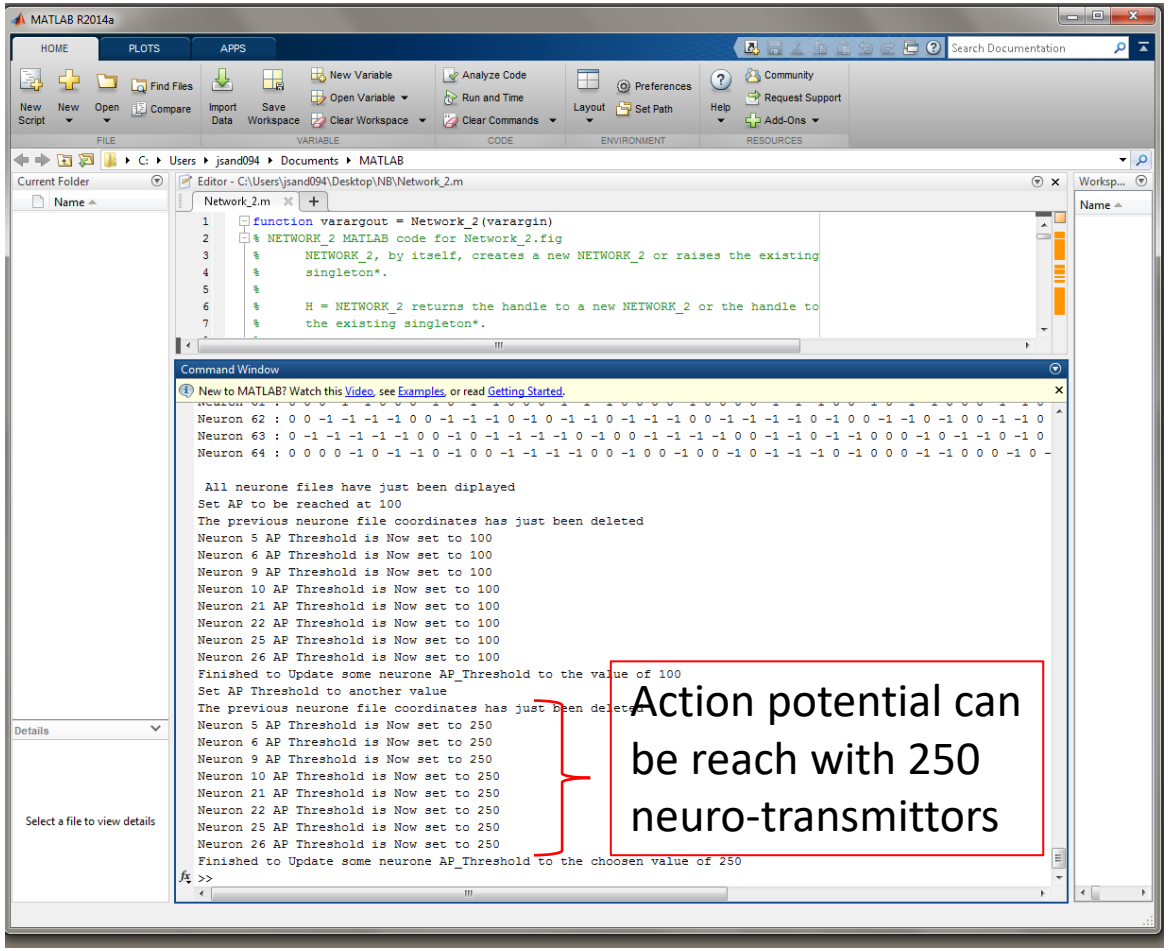
4-First Results

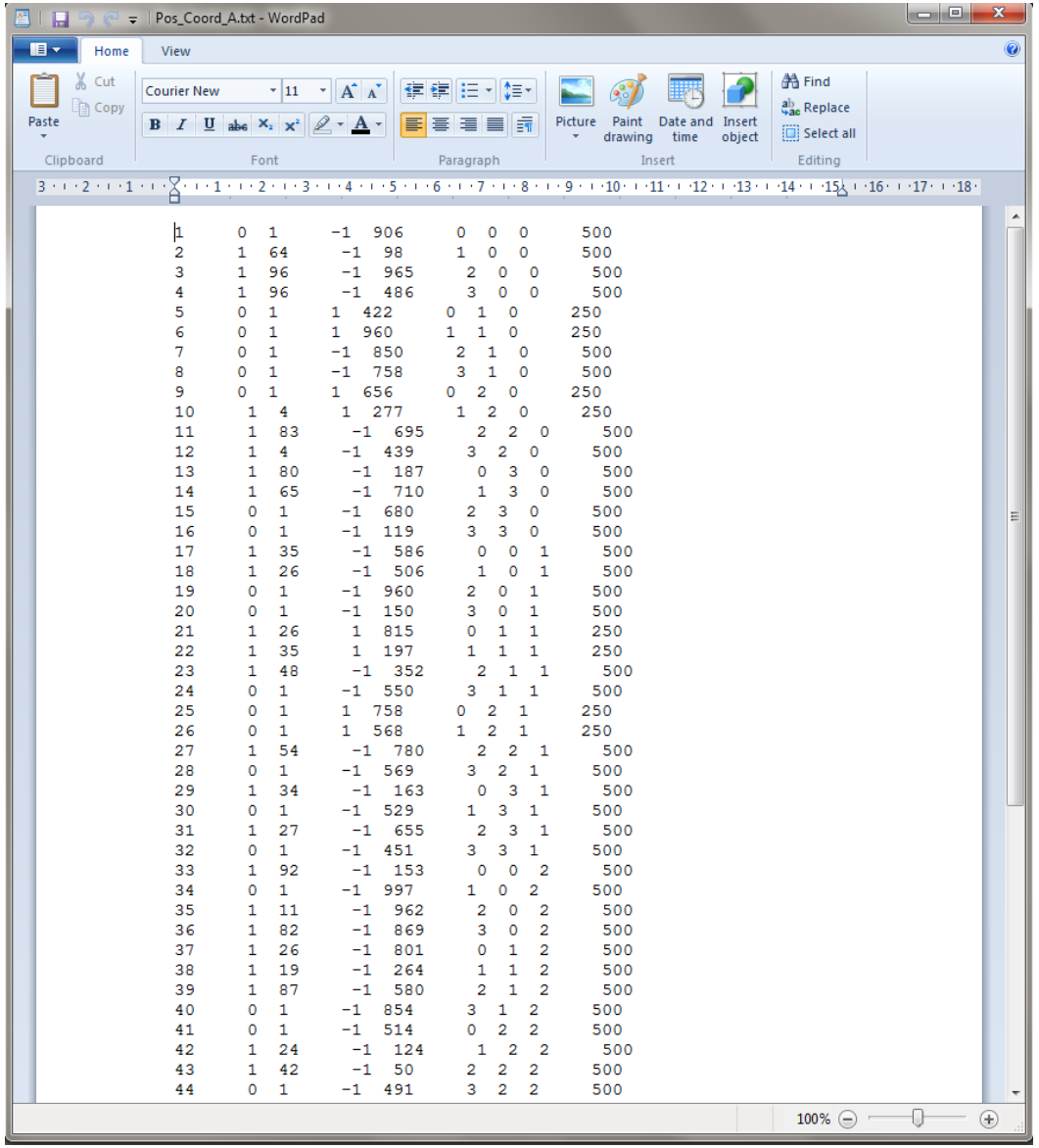
Set selected Neurons Action Potential to be reached at another number of neuro-transmitors.

Random value here is 250

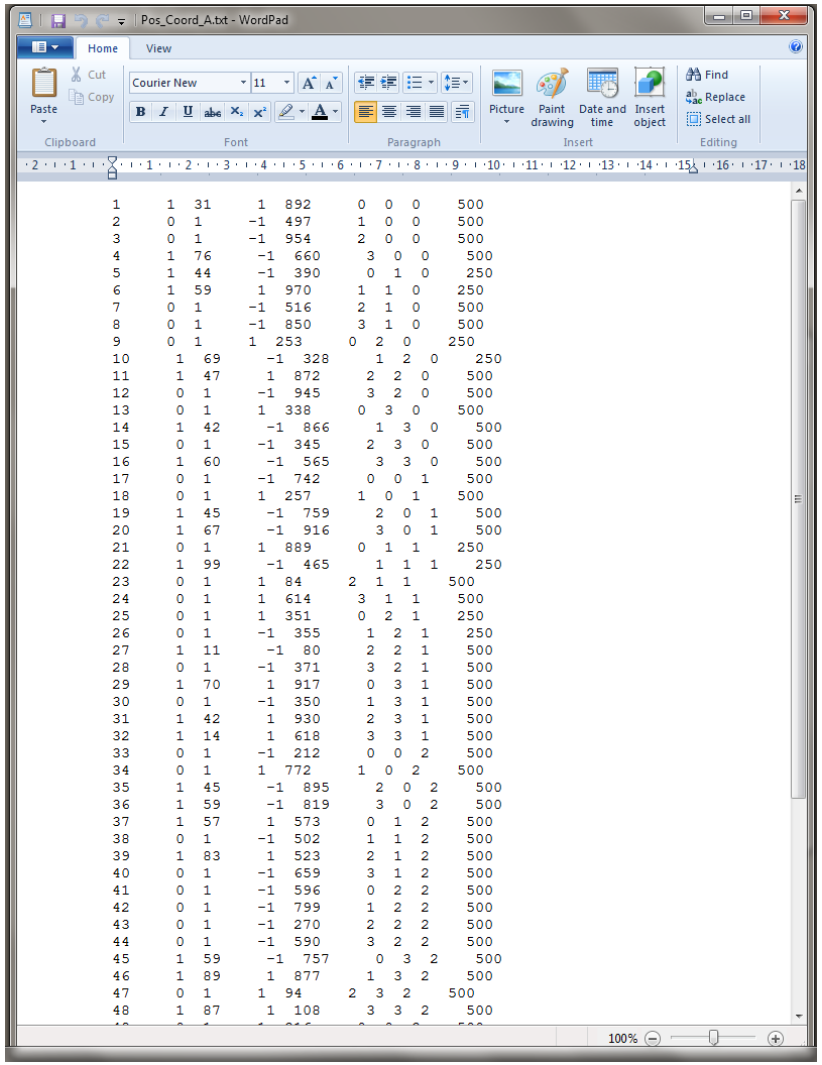


4-First Results

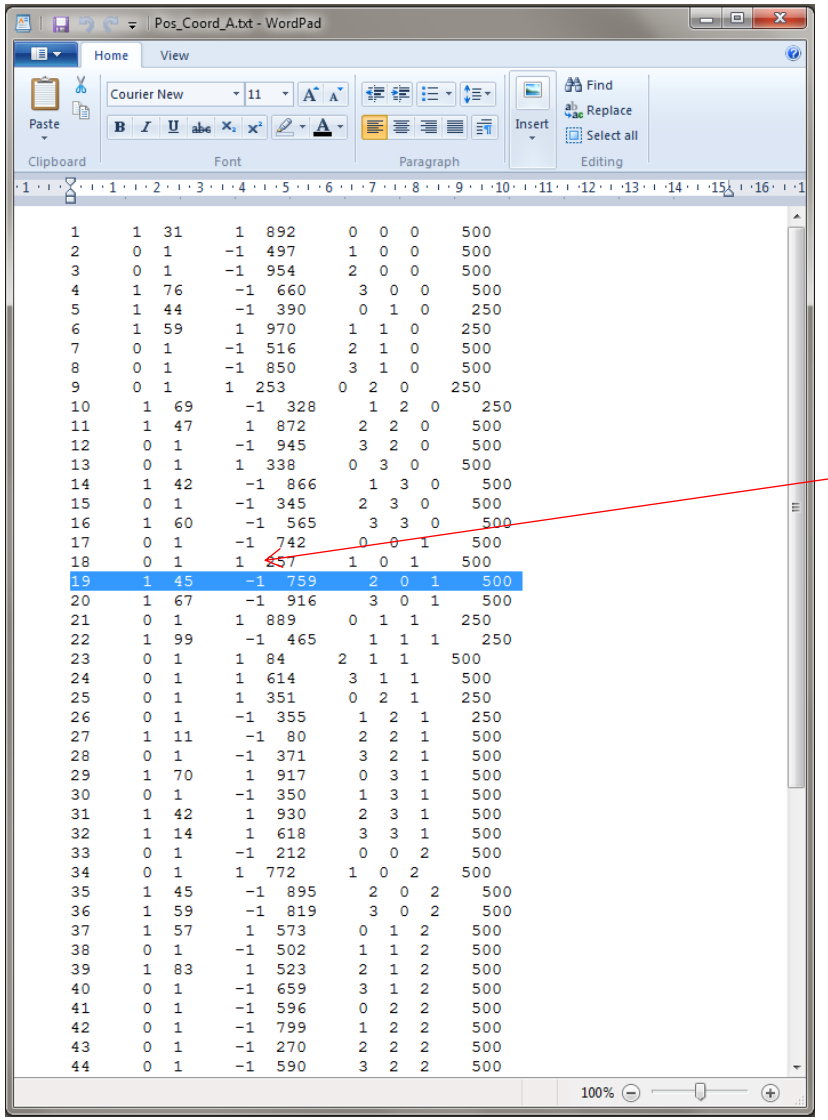




Let s randomly take Neuron 19



1	1	31	1	892	0	0	0	500
2	0	1	-1	497	1	0	0	500
3	0	1	-1	954	2	0	0	500
4	1	76	-1	660	3	0	0	500
5	1	44	-1	390	0	1	0	250
6	1	59	1	970	1	1	0	250
7	0	1	-1	516	2	1	0	500
8	0	1	-1	850	3	1	0	500
9	0	1	1	253	0	2	0	250
10	1	69	-1	328	1	2	0	250
11	1	47	1	872	2	2	0	500
12	0	1	-1	945	3	2	0	500
13	0	1	1	338	0	3	0	500
14	1	42	-1	866	1	3	0	500
15	0	1	-1	345	2	3	0	500
16	1	60	-1	565	3	3	0	500
17	0	1	-1	742	0	0	1	500
18	0	1	1	257	1	0	1	500
19	1	45	-1	759	2	0	1	500
20	1	67	-1	916	3	0	1	500
21	0	1	1	889	0	1	1	250
22	1	99	-1	465	1	1	1	250
23	0	1	1	84	2	1	1	500
24	0	1	1	614	3	1	1	500
25	0	1	1	351	0	2	1	250
26	0	1	-1	355	1	2	1	250
27	1	11	-1	80	2	2	1	500
28	0	1	-1	371	3	2	1	500
29	1	70	1	917	0	3	1	500
30	0	1	-1	350	1	3	1	500
31	1	42	1	930	2	3	1	500
32	1	14	1	618	3	3	1	500
33	0	1	-1	212	0	0	2	500
34	0	1	1	772	1	0	2	500
35	1	45	-1	895	2	0	2	500
36	1	59	-1	819	3	0	2	500
37	1	57	1	573	0	1	2	500
38	0	1	-1	502	1	1	2	500
39	1	83	1	523	2	1	2	500
40	0	1	-1	659	3	1	2	500
41	0	1	-1	596	0	2	2	500
42	0	1	-1	799	1	2	2	500
43	0	1	-1	270	2	2	2	500
44	0	1	-1	590	3	2	2	500
45	1	59	-1	757	0	3	2	500
46	1	89	1	877	1	3	2	500
47	0	1	1	94	2	3	2	500
48	1	87	1	108	3	3	2	500



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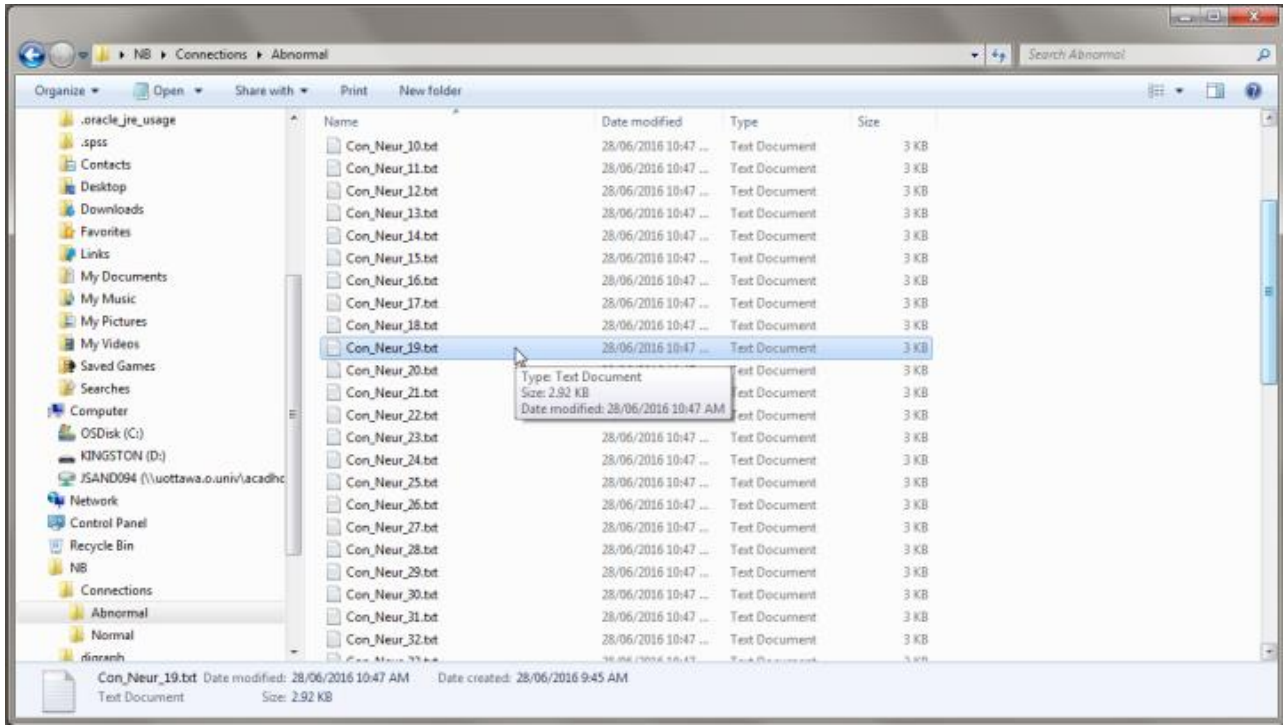
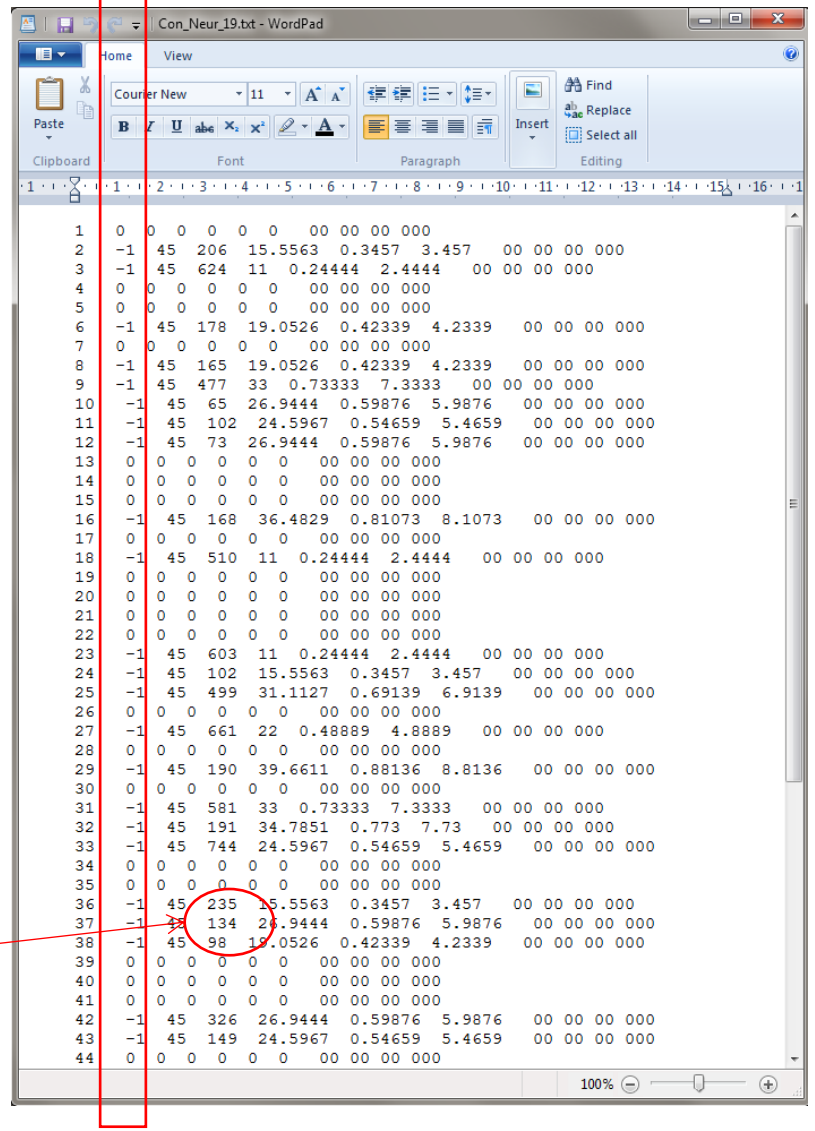
3	0	1	-1	954	2	0	0	500
4	1	76	-1	660	3	0	0	500
5	1	44	-1	390	0	1	0	250
6	1	59	1	970	1	1	0	250
7	0	1	-1	516	2	1	0	500
8	0	1	-1	850	3	1	0	500
9	0	1	1	253	0	2	0	250
10	1	69	-1	328	1	2	0	250
11	1	47	1	872	2	2	0	500
12	0	1	-1	945	3	2	0	500
13	0	1	1	338	0	3	0	500
14	1	42	-1	866	1	3	0	500
15	0	1	-1	345	2	3	0	500
16	1	60	-1	565	3	3	0	500
17	0	1	-1	742	0	0	1	500
18	0	1	1	257	1	0	1	500
19	1	45	-1	759	2	0	1	500
20	1	67	-1	916	3	0	1	500
21	0	1	1	889	0	1	1	250
22	1	99	-1	465	1	1	1	250
23	0	1	1	84	2	1	1	500
24	0	1	1	614	3	1	1	500
25	0	1	1	351	0	2	1	250
26	0	1	-1	355	1	2	1	250
27	1	11	-1	80	2	2	1	500
28	0	1	-1	371	3	2	1	500
29	1	70	1	917	0	3	1	500
30	0	1	-1	350	1	3	1	500
31	1	42	1	930	2	3	1	500
32	1	14	1	618	3	3	1	500
33	0	1	-1	212	0	0	2	500
34	0	1	1	772	1	0	2	500
35	1	45	-1	895	2	0	2	500
36	1	59	-1	819	3	0	2	500
37	1	57	1	573	0	1	2	500
38	0	1	-1	502	1	1	2	500
39	1	83	1	523	2	1	2	500
40	0	1	-1	659	3	1	2	500
41	0	1	-1	596	0	2	2	500
42	0	1	-1	799	1	2	2	500
43	0	1	-1	270	2	2	2	500
44	0	1	-1	590	3	2	2	500

It is an inhibitor (-1)

He has either 0 or 1 inhibition connection with its neighboors



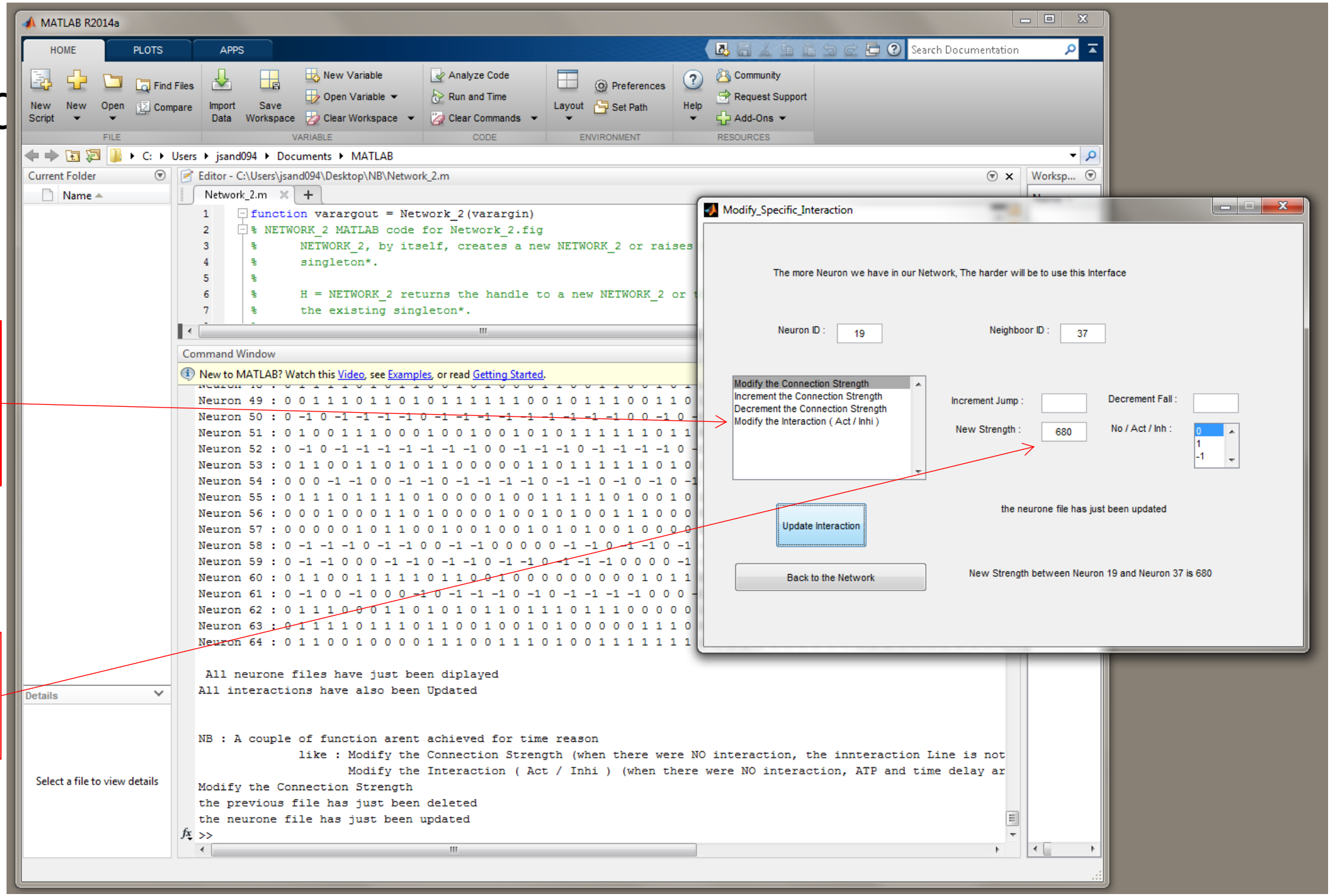


Its current strength with Neuron 37 is 134

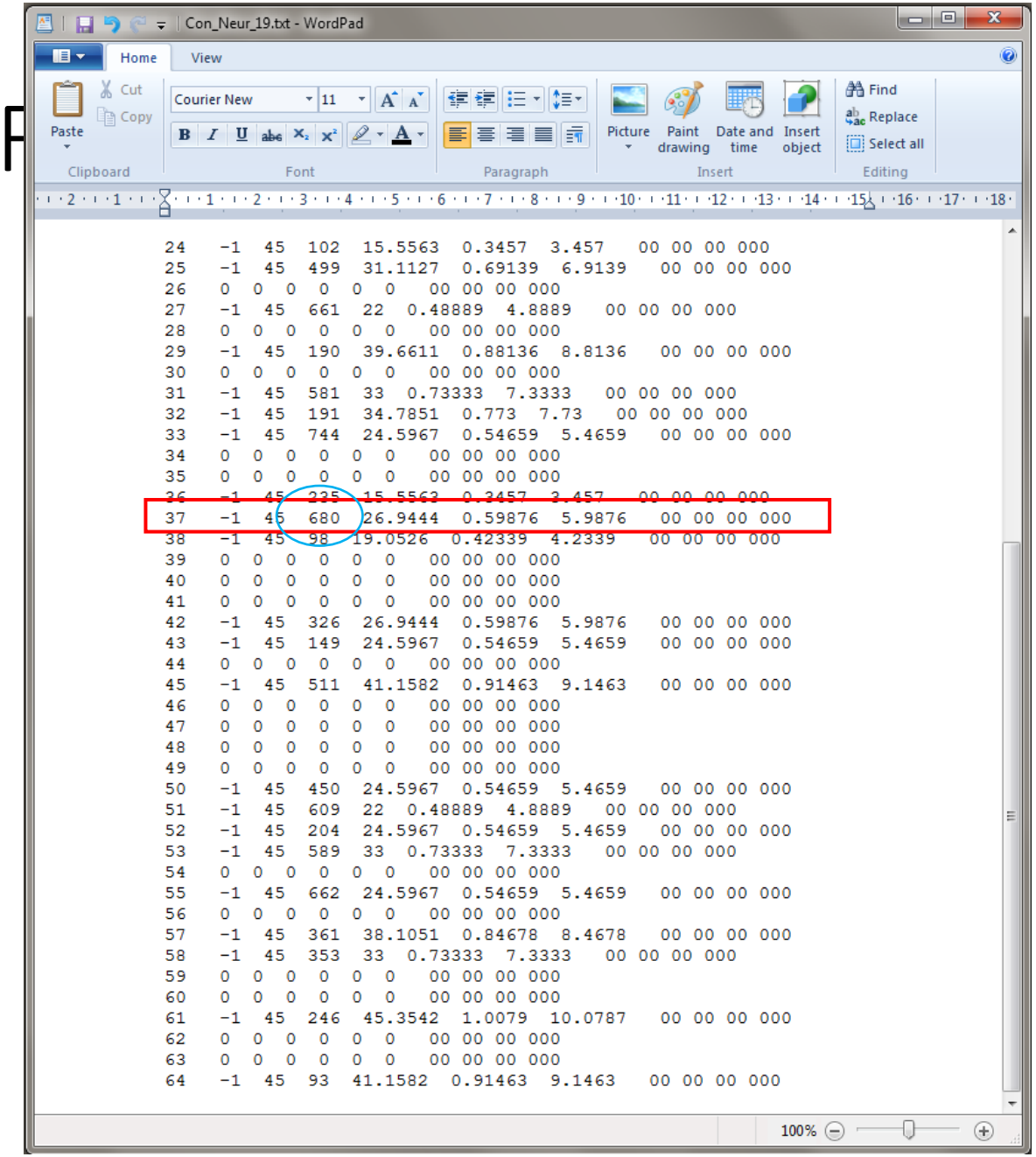
Moc

The last request in the listbox is not achieved for time reasons.

We update that strength to 680



Back to the F


Con_Neur_19.txt - WordPad
Home
View
Cut
Copy
Paste
Courier New
11
Picture
Paint drawing
Date and time
Insert object
Find
Replace
Select all
Clipboard
Font
Paragraph
Insert
Editing
24 -1 45 102 15.5563 0.3457 3.457 00 00 00 000
25 -1 45 499 31.1127 0.69139 6.9139 00 00 00 000
26 0 0 0 0 0 0 00 00 00 000
27 -1 45 661 22 0.48889 4.8889 00 00 00 000
28 0 0 0 0 0 0 00 00 00 000
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41 0 0 0 0 0 0 00 00 00 000
42 -1 45 326 26.9444 0.59876 5.9876 00 00 00 000
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48 0 0 0 0 0 0 00 00 00 000
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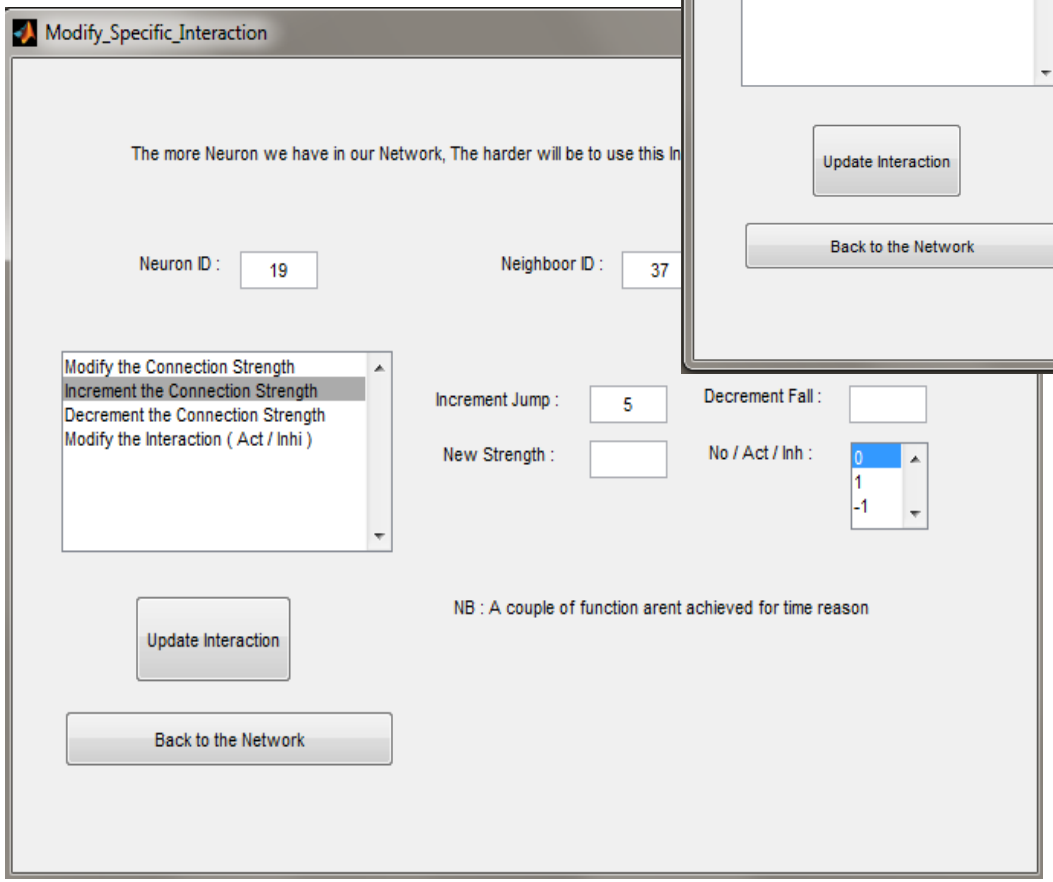
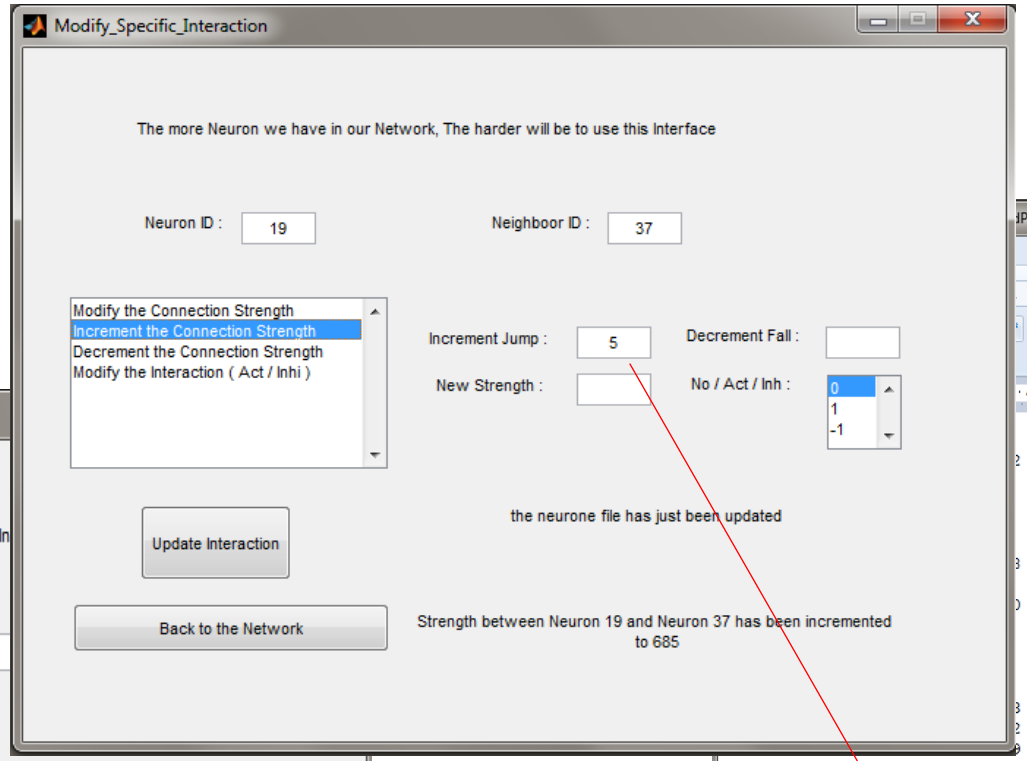
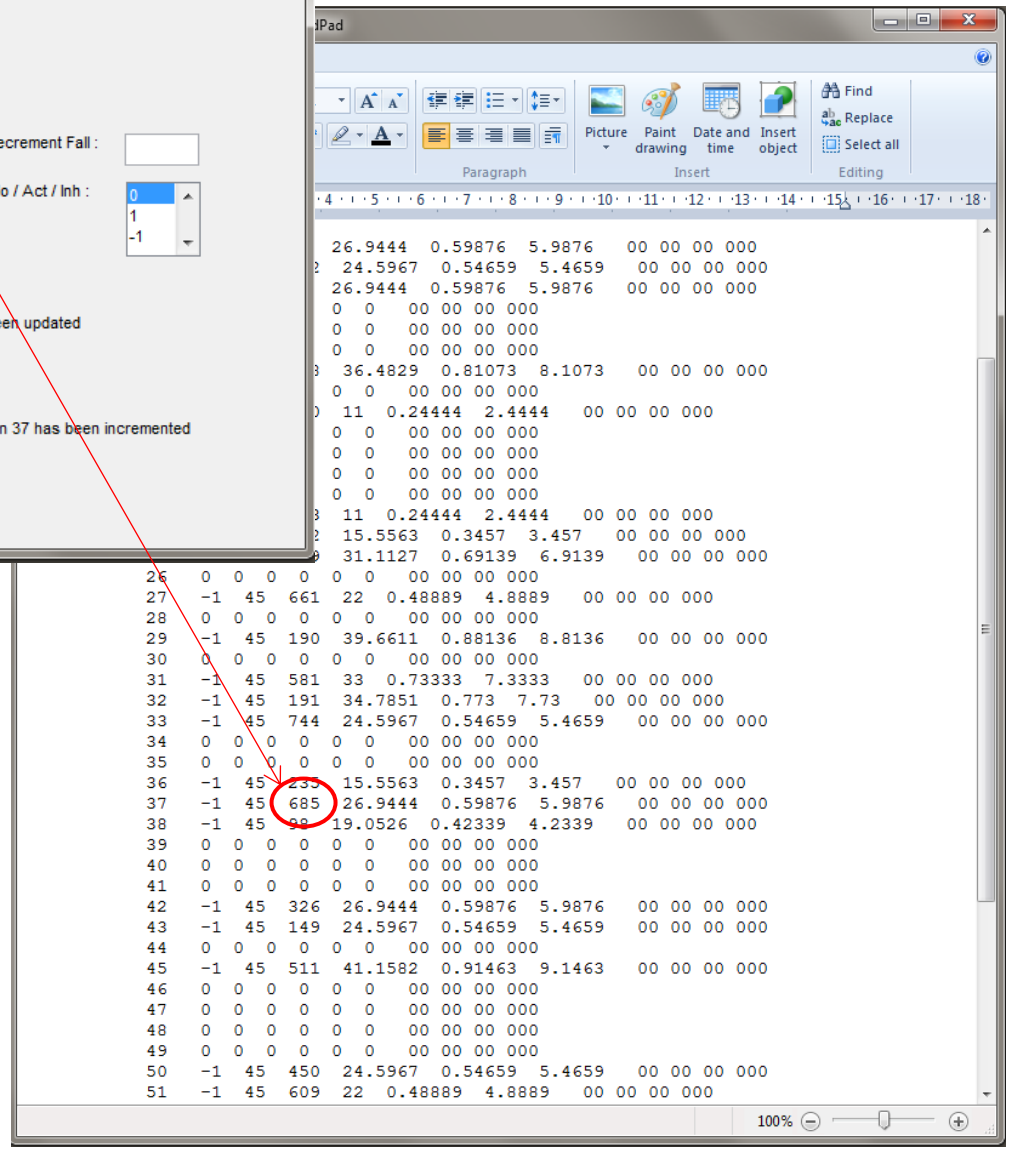
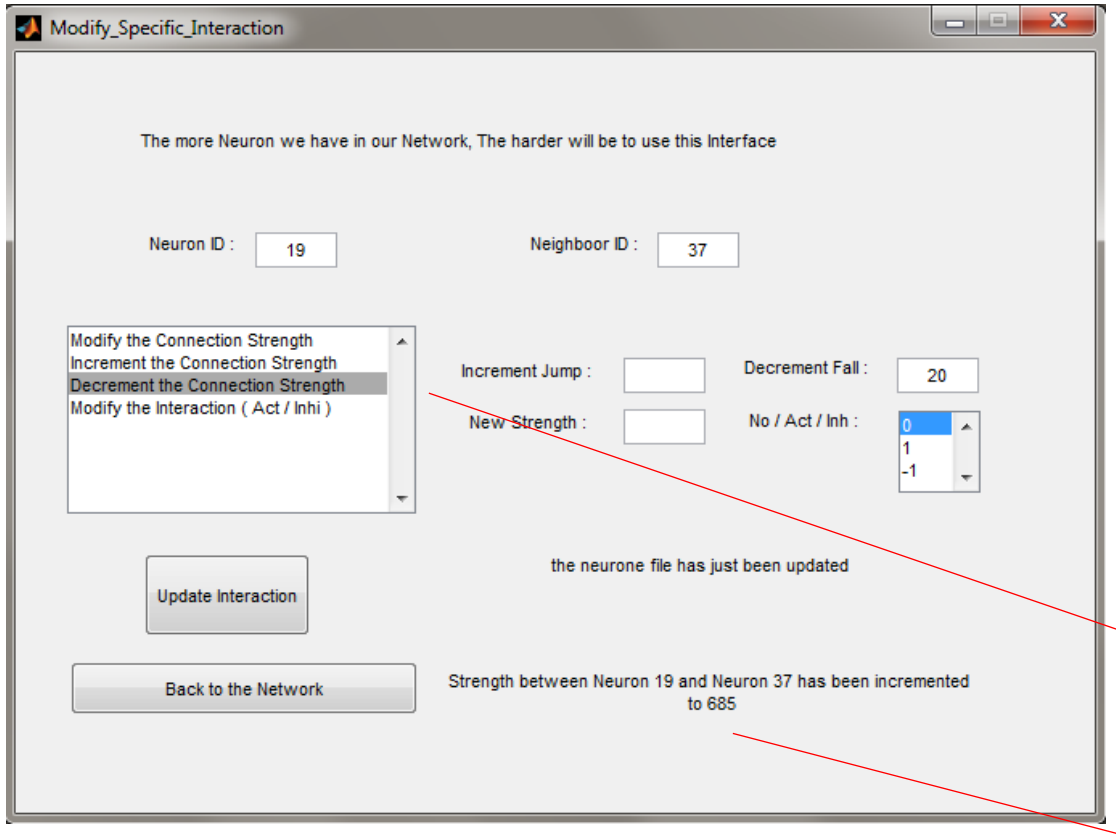
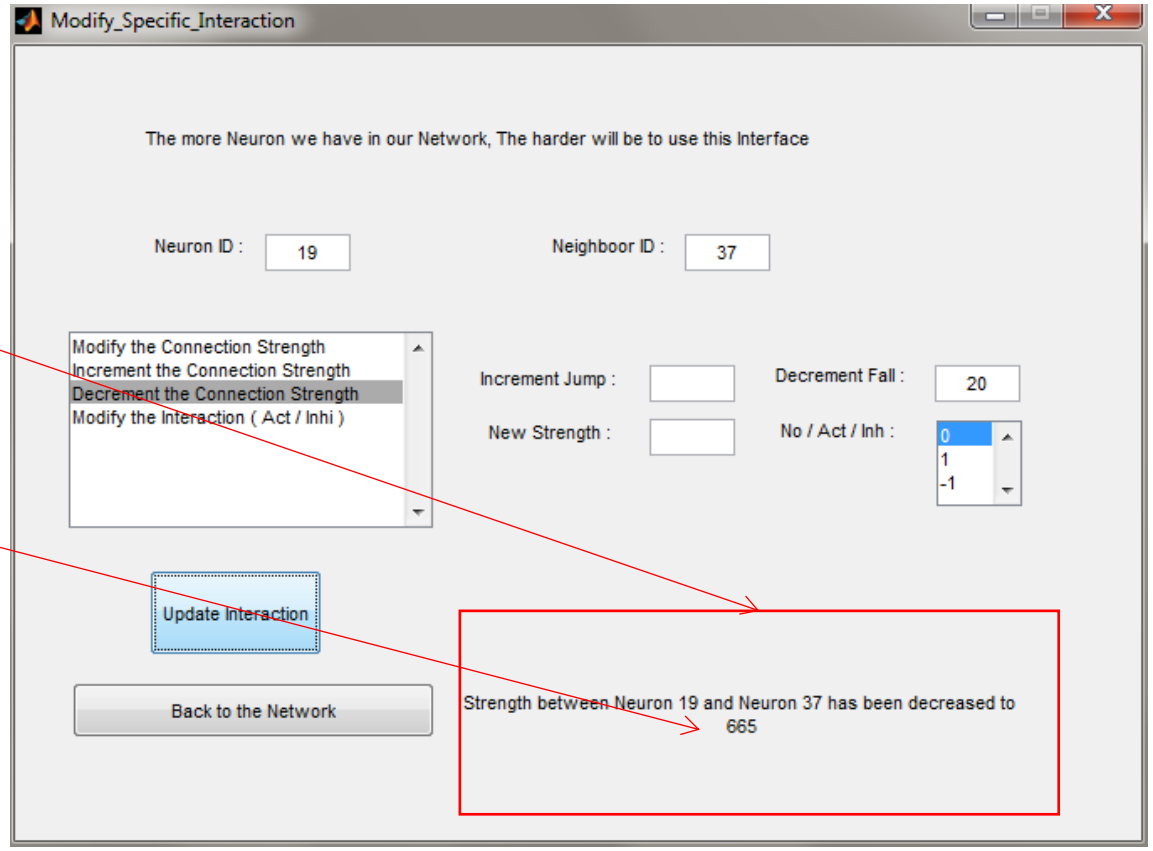
53 -1 45 589 33 0.73333 7.3333 00 00 00 000
54 0 0 0 0 0 0 00 00 00 000
55 -1 45 662 24.5967 0.54659 5.4659 00 00 00 000
56 0 0 0 0 0 0 00 00 00 000
57 -1 45 361 38.1051 0.84678 8.4678 00 00 00 000
58 -1 45 353 33 0.73333 7.3333 00 00 00 000
59 0 0 0 0 0 0 00 00 00 000
60 0 0 0 0 0 0 00 00 00 000
61 -1 45 246 45.3542 1.0079 10.0787 00 00 00 000
62 0 0 0 0 0 0 00 00 00 000
63 0 0 0 0 0 0 00 00 00 000
64 -1 45 93 41.1582 0.91463 9.1463 00 00 00 000
100%


Modify_Specific_Interaction
The more Neuron we have in our Network, The harder will be to use this In
Neuron ID :
19
Neighboor ID :
37
Modify the Connection Strength
Increment the Connection Strength
Decrement the Connection Strength
Modify the Interaction (Act / Inhi)
Increment Jump :
5
Decrement Fall :
New Strength :
No / Act / Inh :
0
1
-1
Update Interaction
NB : A couple of function arent achieved for time reason
Back to the Network

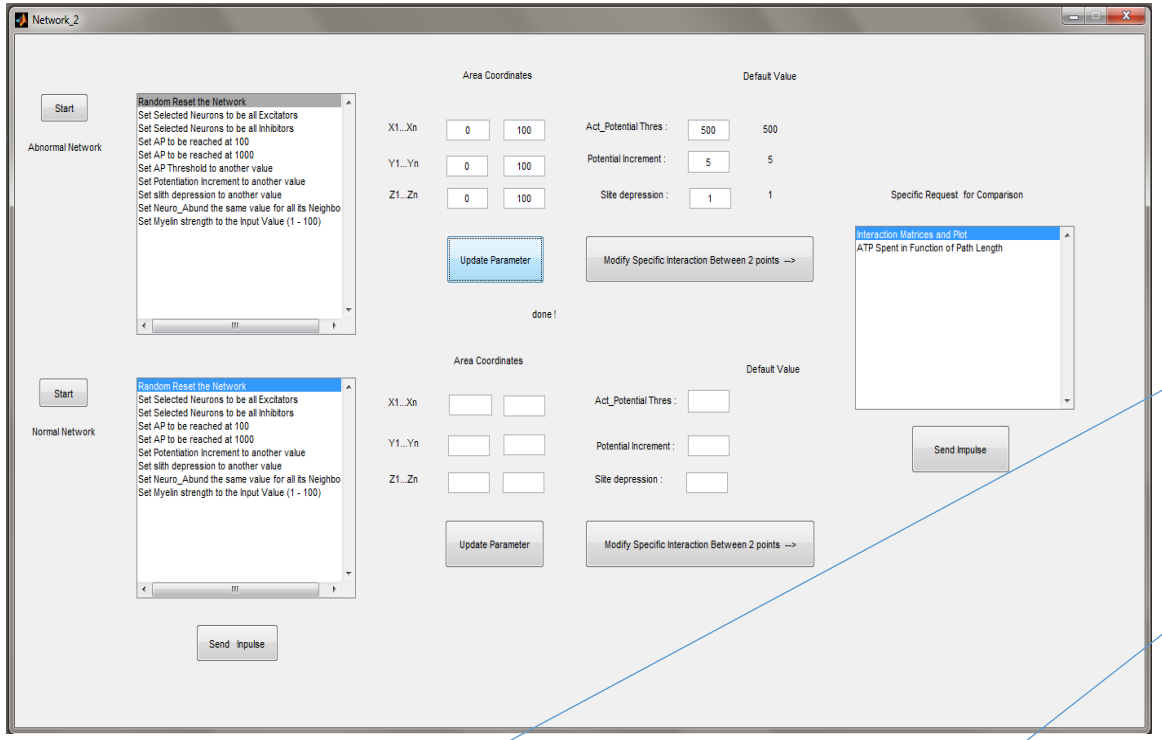

Modify_Specific_Interaction
The more Neuron we have in our Network, The harder will be to use this Interface
Neuron ID :
19
Neighboor ID :
37
Modify the Connection Strength
Increment the Connection Strength
Decrement the Connection Strength
Modify the Interaction (Act / Inhi)
Increment Jump :
5
Decrement Fall :
New Strength :
No / Act / Inh :
0
1
-1
Update Interaction
the neurone file has just been updated
Back to the Network
Strength between Neuron 19 and Neuron 37 has been incremented to 685

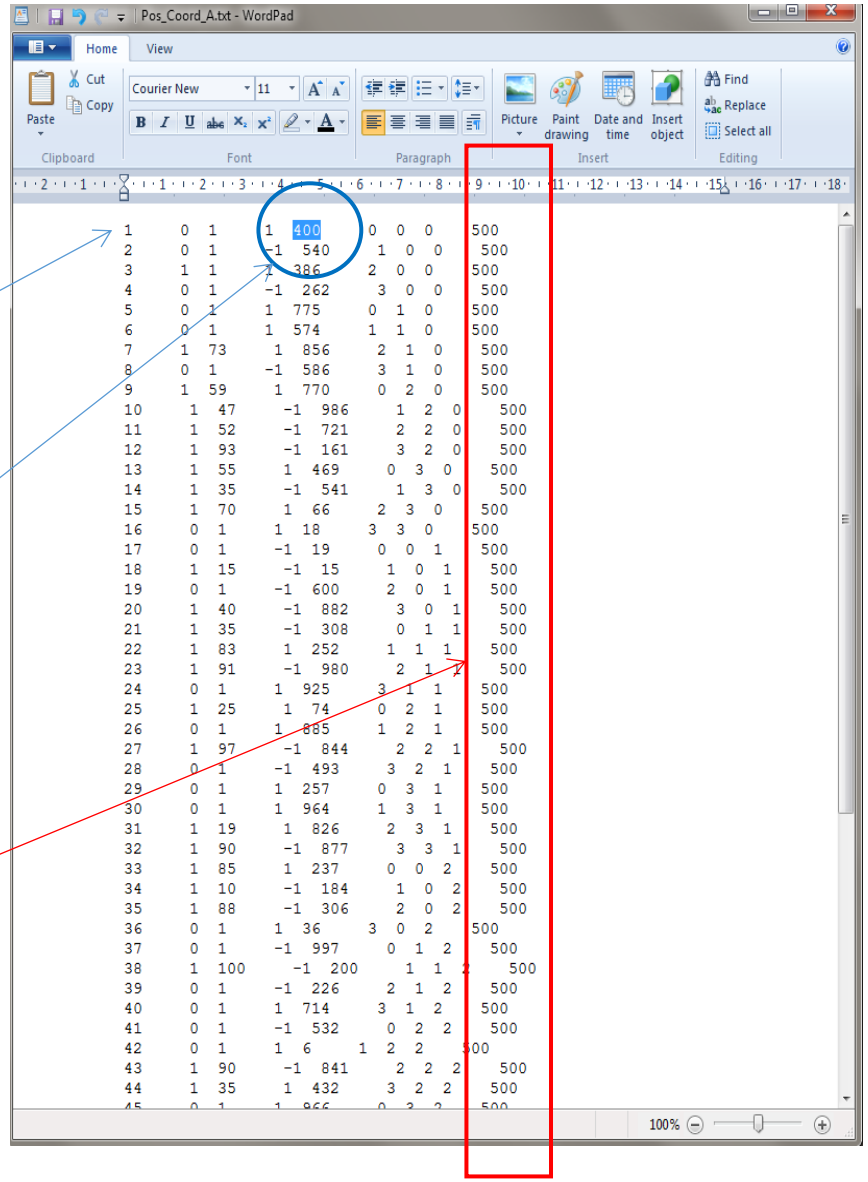

Find
Replace
Select all
Picture
Paint drawing
Date and time
Insert object
Paragraph
Insert
Editing
26.9444 0.59876 5.9876 00 00 00 000
24.5967 0.54659 5.4659 00 00 00 000
26.9444 0.59876 5.9876 00 00 00 000
0 0 00 00 00 000
0 0 00 00 00 000
0 0 00 00 00 000
36.4829 0.81073 8.1073 00 00 00 000
0 0 00 00 00 000
11 0.24444 2.4444 00 00 00 000
0 0 00 00 00 000
0 0 00 00 00 000
0 0 00 00 00 000
0 0 00 00 00 000
11 0.24444 2.4444 00 00 00 000
15.5563 0.3457 3.457 00 00 00 000
31.1127 0.69139 6.9139 00 00 00 000
26 0 0 0 0 0 0 00 00 00 000
27 -1 45 661 22 0.48889 4.8889 00 00 00 000
28 0 0 0 0 0 0 00 00 00 000
29 -1 45 190 39.6611 0.88136 8.8136 00 00 00 000
30 0 0 0 0 0 0 00 00 00 000
31 -1 45 581 33 0.73333 7.3333 00 00 00 000
32 -1 45 191 34.7851 0.773 7.73 00 00 00 000
33 -1 45 744 24.5967 0.54659 5.4659 00 00 00 000
34 0 0 0 0 0 0 00 00 00 000
35 0 0 0 0 0 0 00 00 00 000
36 -1 45 235 15.5563 0.3457 3.457 00 00 00 000
37 -1 45 685 26.9444 0.59876 5.9876 00 00 00 000
38 -1 45 98 19.0526 0.42339 4.2339 00 00 00 000
39 0 0 0 0 0 0 00 00 00 000
40 0 0 0 0 0 0 00 00 00 000
41 0 0 0 0 0 0 00 00 00 000
42 -1 45 326 26.9444 0.59876 5.9876 00 00 00 000
43 -1 45 149 24.5967 0.54659 5.4659 00 00 00 000
44 0 0 0 0 0 0 00 00 00 000
45 -1 45 511 41.1582 0.91463 9.1463 00 00 00 000
46 0 0 0 0 0 0 00 00 00 000
47 0 0 0 0 0 0 00 00 00 000
48 0 0 0 0 0 0 00 00 00 000
49 0 0 0 0 0 0 00 00 00 000
50 -1 45 450 24.5967 0.54659 5.4659 00 00 00 000
51 -1 45 609 22 0.48889 4.8889 00 00 00 000
100%


Modify_Specific_Interaction
The more Neuron we have in our Network, The harder will be to use this Interface
Neuron ID :
19
Neighboor ID :
37
Modify the Connection Strength
Increment the Connection Strength
Decrement the Connection Strength
Modify the Interaction (Act / Inhi)
Increment Jump :
Decrement Fall :
20
New Strength :
No / Act / Inh :
0
1
-1
Update Interaction
the neurone file has just been updated
Back to the Network
Strength between Neuron 19 and Neuron 37 has been incremented to 685


Modify_Specific_Interaction
The more Neuron we have in our Network, The harder will be to use this Interface
Neuron ID :
19
Neighboor ID :
37
Modify the Connection Strength
Increment the Connection Strength
Decrement the Connection Strength
Modify the Interaction (Act / Inhi)
Increment Jump :
Decrement Fall :
20
New Strength :
No / Act / Inh :
0
1
-1
Update Interaction
Back to the Network
Strength between Neuron 19 and Neuron 37 has been decreased to 665

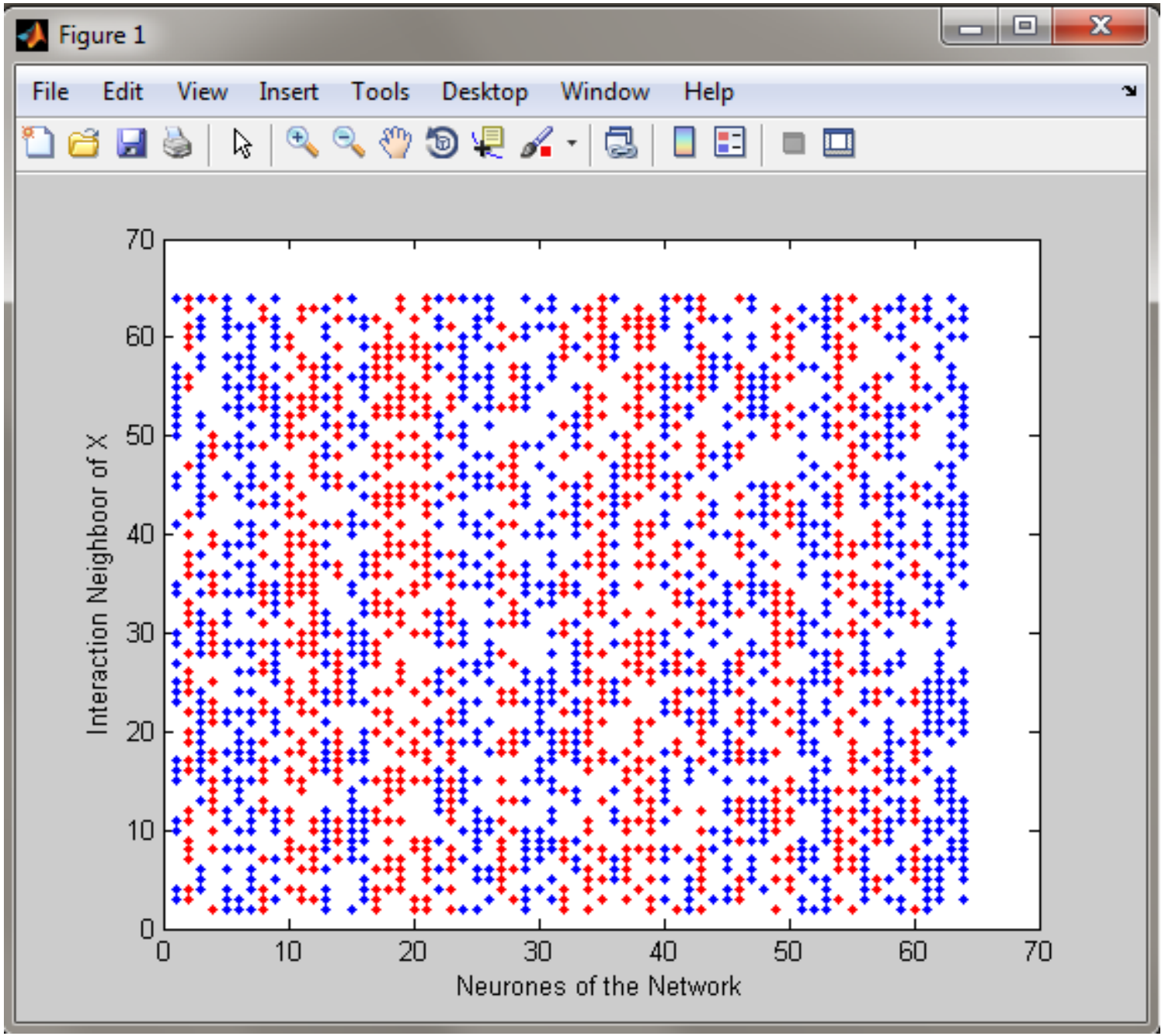
Let s go back to the Network

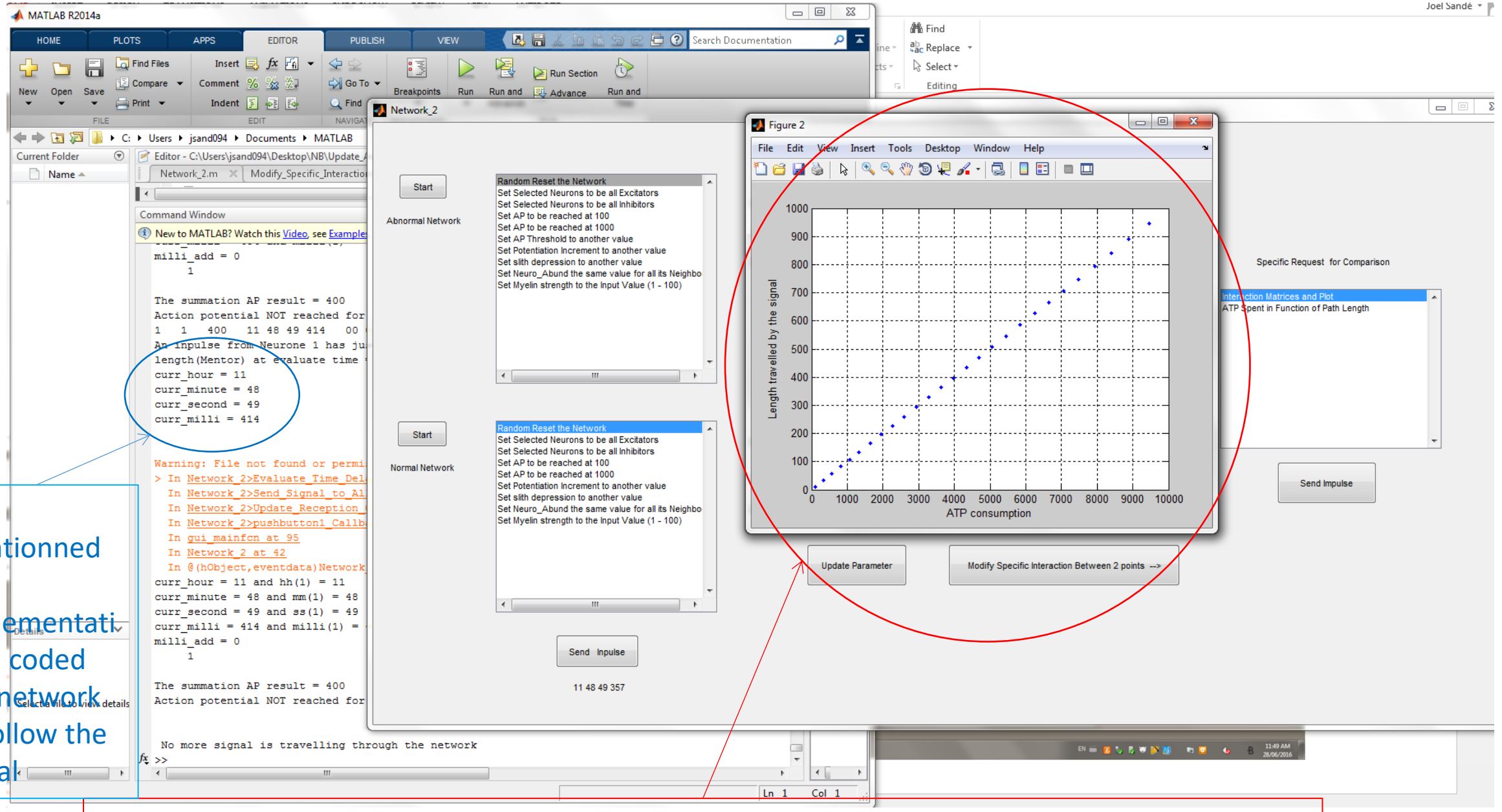




When one submit an impulse, the Neuron1 is the first neuron that it : Receptor Neuron. The last column is the action potential threshold. When neuron 1 will send its signal to its neighboors, for this simulation, I manually put its neurotransmitors (the power with which he excites its neighboors) to 100. In that case, he cannot excite none of its neighboors which threshold is 500 > 100.

After updating the network, this is the interactions profile for this simulation

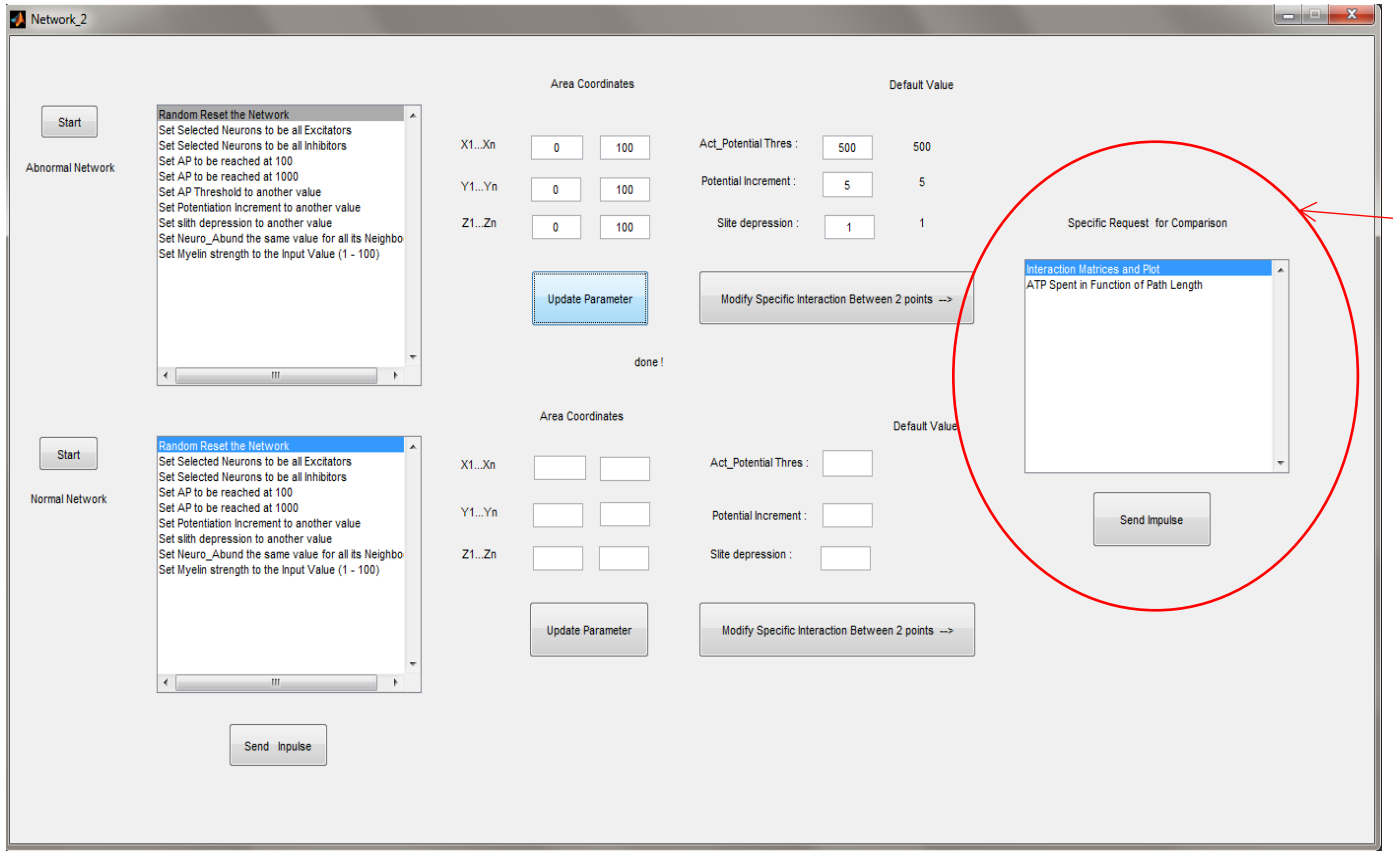




As I mentionned in implementation, I coded the network to follow the signal

When the myelin is not altered, and we consider one neuron at the time, we can see a direct relationship between ATP consumption and Length travelled by the signal.

5-A couple of comparisons



This part is to compare the Normal Network and the Abnormal network. Right now, white I am writing this, I am reviewing a function that unfortunately saturates Matlab while running the whole simulation, because of iterations error. Matlab stores too much data, and stop running after.. 5 - 10 min. I will be able to do more simulations once I fixe that problem.

Current work

6-Conclusion

- The conclusion we can make from slide 27 is that : When the myelin is not altered, and we consider one neuron at the time, we can see a direct relationship between ATP consumption and Length travelled by the signal.

- Not enough results on the network processing itself because of time constraints.

- However, session 4 provides good results regarding the network implementation.

7-limitation

- As I don t have huge computer to do a multithread,

- 1) I cannot run simultanely both Abnormal and normal Network. I have to run one network at the time.
- 2) As I don t have huge computer to do a multithread, I can only send one signal and wait for that signal to disappear completely before I send another one

Solution : To use Supercomputers to do the simulations

8-Futur work

- I found a function named Digraph available in Matlab 2016. A powerful function that :
  - ✓gives the shorter path in a given network, from a point A to a point B,
  - ✓topology that allow to connect neighbour neuron in specific pattern,
  - ✓… a lot of new stuff we can do, such as representing areas for the frontal lobe, visual lobe, ...

- Run more simulations varying different parameters :
  - ✓I can base the neuroplasticity on function available via matlab 2016 in addition to what I already did.
  - ✓As the brain is lasy, I can easily choose in a simulation to keep only paths that spend the less energy possible and see how it impacts the network topology, using functionalities available on Matlab 2016.

8-Futur work

- I have a solution to implement data memory, and even, artificial intelligence within the system (algorithms based on this work). We can perform reminding based on synaptic-connections. What is interesting with those algorithm, they can give you (in output) only what you input, starting at a completely stupid stage : at the beginning there is no output possible until you start putting repetitively the same inputs.

8-Futur work

- I believe that to understand how disease like Alzheimer and Autism (memory disease) work, we have to get that kind of algorithm coded inside a network (and make difference between different compartments of the brain), and if that works well in the simulations, we can understand far beyond ATP and length issue, but also at the connection level.

- → this is not for today ☺