Division of Computing, Engineering and Mathematical Sciences
Department of Computing, University of Kent *in Canterbury*

Cognitive Neural Networks
Assignment No.1

By

Lukasz Ryszard Tomaszewski

Computer Science (Artificial Intelligence) MSc

Module CO836: Cognitive Neural Networks

LaTeX Word Count: 1935

04th Nov – 25th Nov 2021

Contents

1 Assignment Brief

The assessment is based upon the Emergent explorations to be found in "Computational Explorations in Cognitive Neuroscience". Note that you have covered some of these explorations in the practical classes.

Can you submit your assignment as a pdf document? If you write anything by hand, e.g. maths derivations, can you include that as an image, preferably in the same document as the rest of your assessment.

2 Exploration Questions

2.1 Q1: Exploration 2.6.1 (Page 49)

2.1.1 Task 2.1

Question 2.1 (a) *Describe the effects on the neural response of increasing* g_{bar_e} *to .5, and of decreasing it to .3.* ***(b)*** *Is there a qualitative difference in the unit activation (act) between these two changes of magnitude .1 away from the initial .4 value?* ***(c)*** *What important aspect of the point neuron activation function does this reveal? [Mark: 11]*

When increasing the value of the excitatory conductance (g_{bar_e}) from 0.4 to 0.5, the value of the activation value for a neural response (receiving unit) increases from 0.7204 to 0.9445 as showing in fig. 1 and fig. 2 and indicating a relationship between the excitatory conductance (g_{bar_e}) and the receiving unit. When changing g_{bar_e} from 0.4/0.5 to 0.3, the neural response is null as seen in fig. 3, where the receiving unit doesn't pick up any value despite the sending unit (g_{bar_i}) remaining the same. When comparing the graphical output data shown in fig. 4, fig. 5 and fig. 6 for the 3 values of g_{bar_e} (0.4, 0.5 and 0.3 respectively). The activation value stems from the membrane potential (V_m), which for all 3 graphs shows a 0.2241 increase for g_{bar_e} at 0.4 to 0.5, Ultimately when g_{bar_e} equals 0.3 then the activation value flat lines in fig. 6 as it return a null value. This highlights how the point neuron activation function relates to the input excitatory conductance directly affects the total activation value.

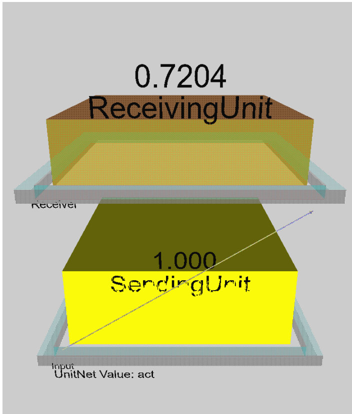

Figure 1: Visual representation of the sending and receiving units with g_{bar_e}.

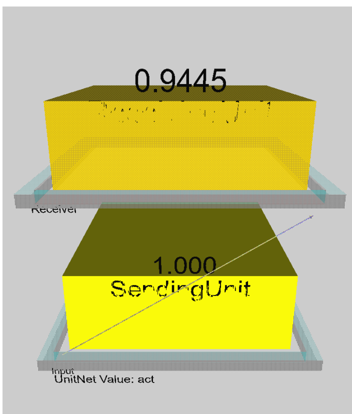

Figure 2: Visual representation of the sending and receiving units with g_{bar_e}.

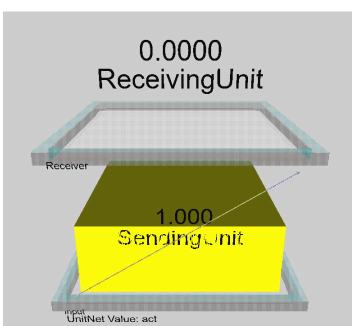

Figure 3: Visual representation of the sending and receiving units with g_{bar_e}.

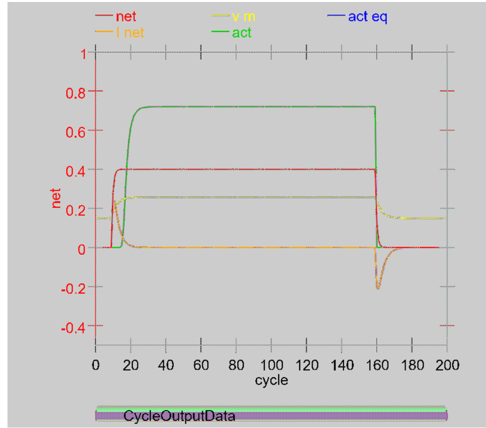

Figure 4: Graphical output data of fig. 1 when running a value of 0.4 for g_{bar_e}.

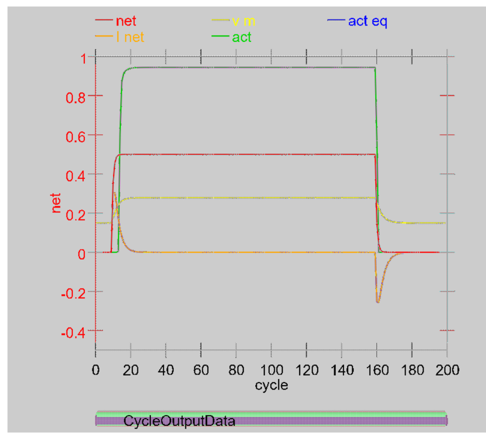

Figure 5: Graphical output data of fig. 2 when running a value of 0.5 for g_{bar_e}.

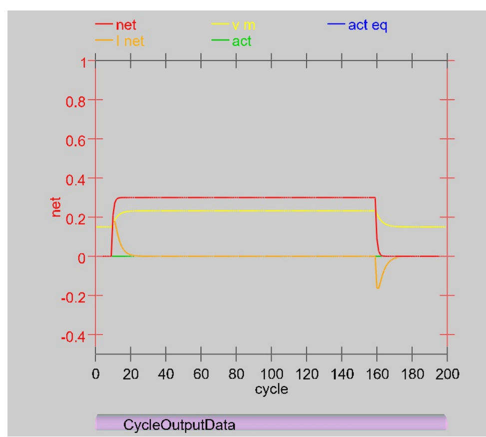

Figure 6: Graphical output data of fig. 3 when running a value of 0.3 for g_{bar_e}.

2.1.2 Task 2.2

Question 2.2 (a) *To 3 decimal places, what value of g_{bar_e} puts the unit just over threshold? Can you think of a better way of finding this value (Hint: Do you remember an equation for the equilibrium membrane potential given a particular set of inputs?)* ***(b)*** *Compute the exact value of excitatory input required to just reach threshold, showing your math (note that: g_l is always 1 because the leak channels are always open; g_e is 1 when the input is on; inhibition is not present here and can be ignored). Does this agree with your empirically determined value?* ***(Hint: It should!)*** *[Mark: 8]*

By experimenting with different values for g_{bar_e} less than 0.4 to determine the threshold of the receiving unit where its value is limited to 0.0001 at a minimum g_{bar_e} value of 0.324 (restricted to 3 decimal places). By using the equilibrium membrane potential equation, the minimum value of g_{bar_e} can be calculated to which reaches threshold of the neural response.

Equilibrium Membrane Potential Equation:

$$0 = g_e(t)\bar{g}_e(E_e - V_m(t)) + g_i(t)\bar{g}_i(E_i - V_m(t)) + g_l(t)\bar{g}_l(E_l - V_m(t)) \tag{1}$$

Re-Written As:

$$V_m = \frac{g_e\bar{g}_e}{g_e\bar{g}_e + g_i\bar{g}_i + g_l\bar{g}_l}E_e + \frac{g_e\bar{g}_e}{g_e\bar{g}_e + g_i\bar{g}_i + g_l\bar{g}_l}E_i + \frac{g_e\bar{g}_e}{g_e\bar{g}_e + g_i\bar{g}_i + g_l\bar{g}_l}E_l \tag{2}$$

Alternative Formulation:

$$V_m = \frac{g_e\bar{g}_e E_e + g_i\bar{g}_i E_i + 1\bar{g}_l E_l}{g_e\bar{g}_e + g_i\bar{g}_i + g_l\bar{g}_l} \tag{3}$$

Excitatory Input Calculation:

$$V_m = \frac{g_e\bar{g}_e E_e + g_l\bar{g}_l E_l}{g_e\bar{g}_e + g_l\bar{g}_l} \rightarrow \frac{g_e\bar{g}_e E_e + 1\bar{1}E_l}{g_e\bar{g}_e + 1\bar{1}} \rightarrow \frac{g_e\bar{g}_e E_e + E_l}{g_e\bar{g}_e + 1} \tag{4}$$

$$\frac{g_e\bar{g}_e E_e}{g_e\bar{g}_e} = V_m - \frac{E_l}{1} \rightarrow V_m - E_l \tag{5}$$

$$E_e = V_m - E_l \tag{6}$$

2.1.3 Task 2.3

Question 2.3 (a) *How does the response of the unit change when you change g_{bar_l}? Why?* ***(b)*** *How does this differ from changes to g_{bar_e}?* ***(c)*** *Use the same technique you used in the previous question to compute the exact amount of leak current necessary to put the membrane potential exactly at threshold when the g_{bar_e} value is at the default of .4 (show your math). [Mark: 11]*

The original input values are graphical plotted in fig. 7 to provide a reference when changing the value of g_{bar_l}. The reference value of g_{bar_l} is 2.8, where all other variables are set in table 1 and the comparing all the graphical plots, it's clear to see that the activation value of the receiving unit increasing when the original value of g_{bar_l} is decreased, then vice versa where the activation value decreases when g_{bar_l} is increased. When changing g_{bar_e}, the net input is changed whereas the activation value changes as well, where when increasing g_{bar_e}, the activation value increases as well and as it decreases, the activation value decreases also. However in the case of g_{bar_l} as it increases the value of the activation value decreases, the opposite of what happens with g_{bar_e}.

States	g_{bar_e}	g_{bar_l}	g_{bar_i}	g_{bar_h}	g_{bar_a}	Graphical Plot
0	0.4	2.8	1.0	0.1	0.1	fig. 7
1	0.4	3.0	1.0	0.1	0.1	fig. 8
2	0.4	3.2	1.0	0.1	0.1	fig. 9
3	0.4	2.5	1.0	0.1	0.1	fig. 10
4	0.4	2.2	1.0	0.1	0.1	fig. 11

Table 1: Tabulated results of changing g_{bar_l}.

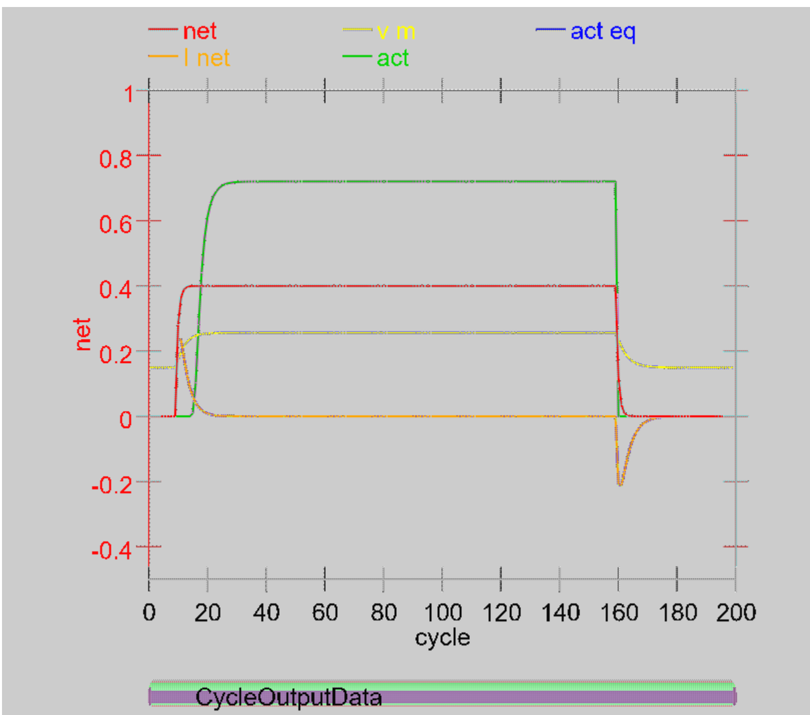

Figure 7: Graphical output of the system where g_{bar_l} is at the original value of 2.8.

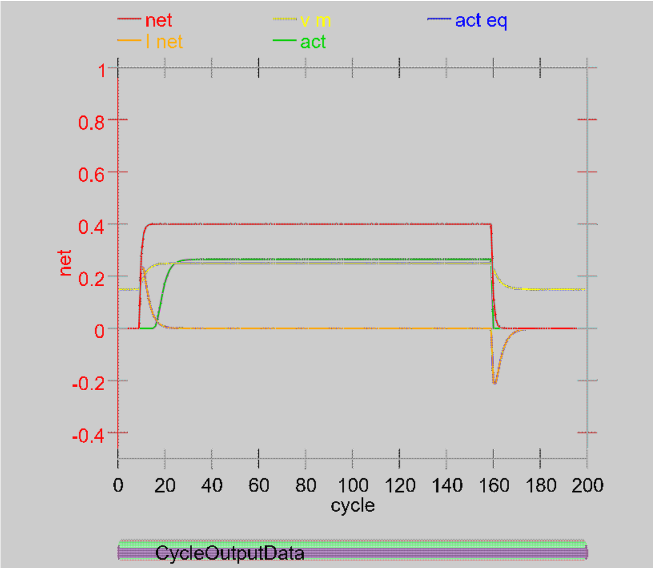

Figure 8: Graphical output of the system where g_{bar_l} is at a value of 3.0.

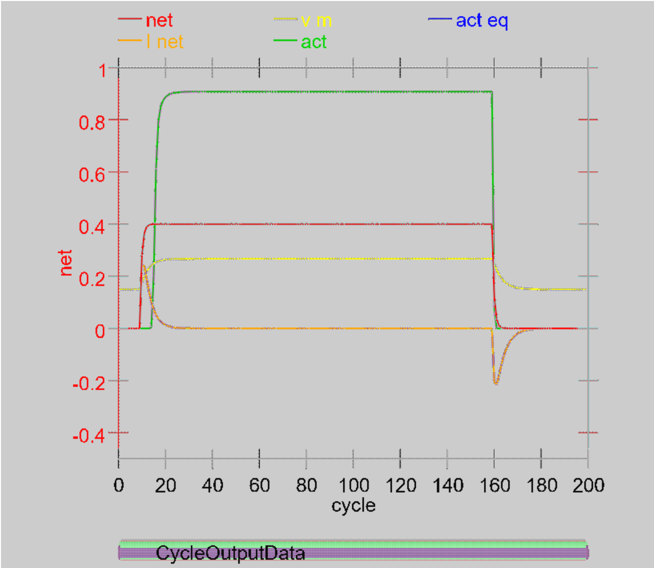

Figure 10: Graphical output of the system where g_{bar_l} is at a value of 2.5.

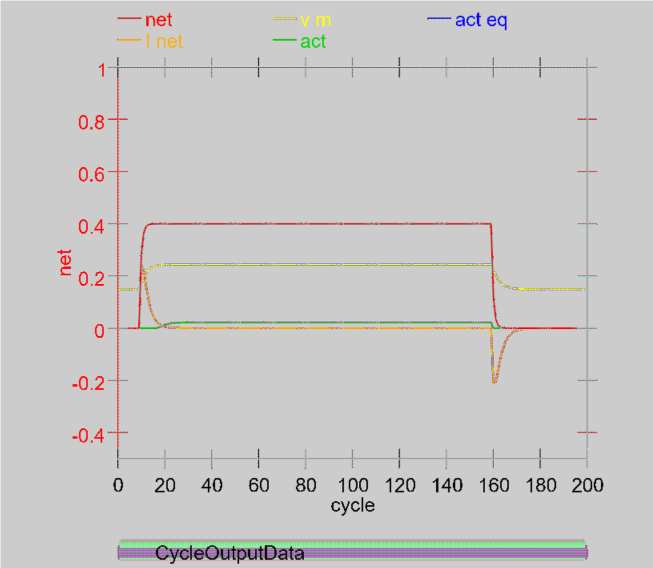

Figure 9: Graphical output of the system where g_{bar_l} is at a value of 3.2.

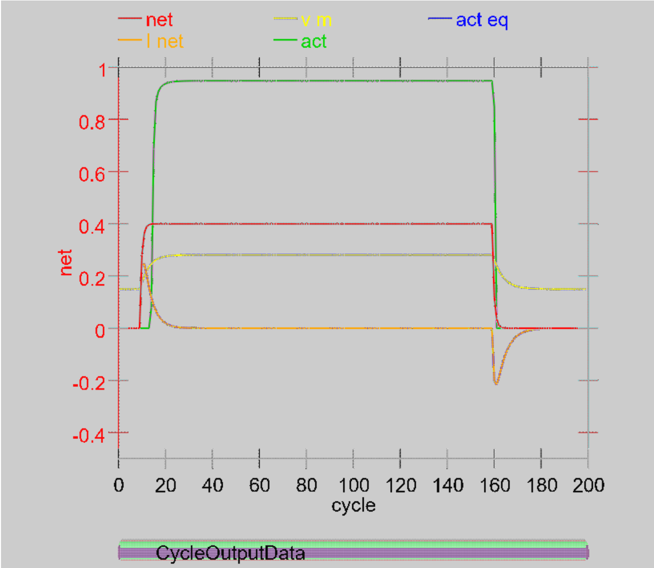

Figure 11: Graphical output of the system where g_{bar_l} is at a value of 2.2.

2.1.4 Task 2.4

Question 2.4 (a) *What happens to the unit's activity if you change the leak reversal potential e_{rev_l} from .15 to 0?* ***(b)*** *What about when you increase it to .2? For both questions, explain the results, taking note of what happens before the input goes on as well as what happens while it is on.* ***(c)*** *What can you conclude about the relationship between the resting potential and the leak reversal potential? [Mark: 11]*

Changing the value of e_{rev_l} form 0.15 to 0 can be seen graphical in fig. 15 and fig. 16. it can be seen when changing the leak reverse potential where the activation level equals to 0 and then when increasing it to 0.2 in fig. 17 the activation value reaches 1 in which influences the resulting membrane potential. When the e_{rev_l} is 0.2 the net current is identical to when e_{rev_l} is 0.15, this is probably due due to the small difference in value but can be seen with the rise of the activation value. However the net current starts negatives within the first 20 cycles (shown in fig. 16) whereas when the value is positive the net current starts positive but both cases equal zero when the activation level is activated as the current is null while the activation level is reached.

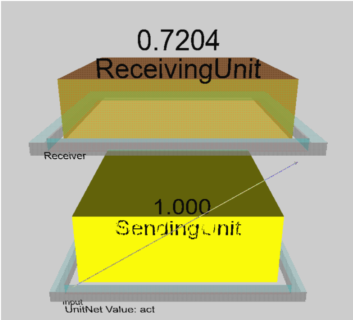

Figure 12: Visual representation of the sending and receiving units with e_{rev_l} at a value of 0.15.

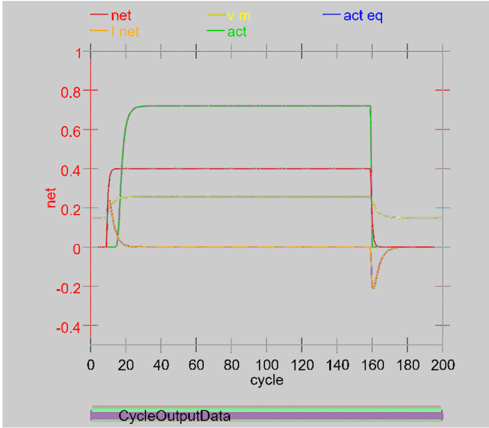

Figure 15: Graphical output data of fig. 12 when running a value of 0.15 for e_{rev_l}.

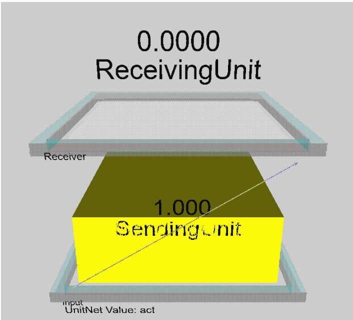

Figure 13: Visual representation of the sending and receiving units with e_{rev_l} at a value of 0.0.

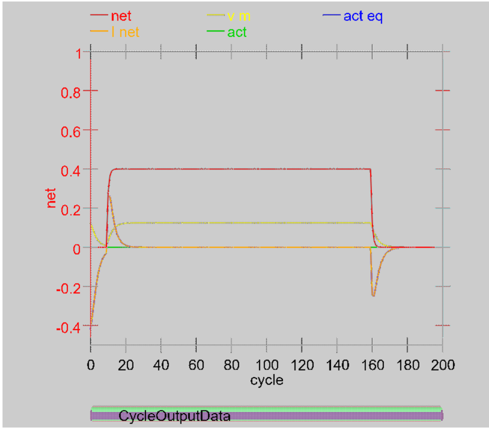

Figure 16: Graphical output data of fig. 13 when running a value of 0.0 for e_{rev_l}.

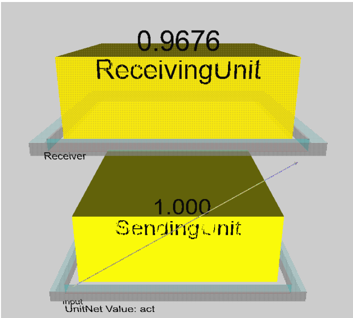

Figure 14: Visual representation of the sending and receiving units with e_{rev_l} at a value of 0.2.

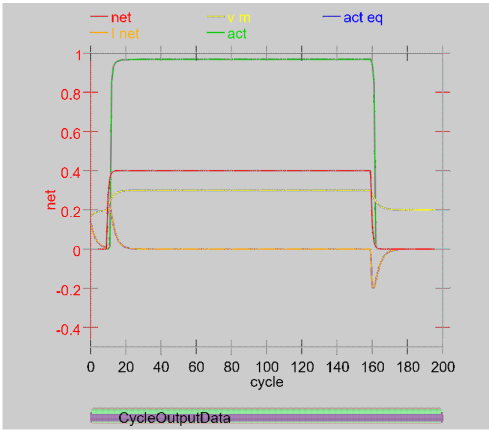

Figure 17: Graphical output data of fig. 14 when running a value of 0.2 for e_{rev_l}.

2.1.5 Task 2.5

Question 2.5 (a) *What happens to the unit's activity if you change the excitatory reversal potential* e_{rev_e} *from 1 to .5? Why does this happen?* ***(b)*** *Can you com- pensate for this by changing the value of* g_{bar_e}*? To two decimal places, use the simulator to find the value of* g_{bar_e} *that gives essentially the same activation value as the default parameters.* ***(c)*** *Then use the same approach as in question 2.2 to solve for the exact value of* g_{bar_e} *that will compensate for this change in* e_{rev_e} *(use .256 for the membrane potential under the default parameters, and show your math). [Mark: 10]*

By changing the excitatory reversal potential e_{rev_e} value from 1.0 to 0.5 as seen in fig. 21, the activation value is zero this is because the excitatory reversal potential must equal to 1 for any response in the activation level as the g_{bar_e} is at 0.4. The defaults parameters gave an activation level of 0.204, in fig. 22 where the value of g_{bar_e} is 1.22 which gives an activation level of 0.7191, this is the closest to the activation level to two decimal places.

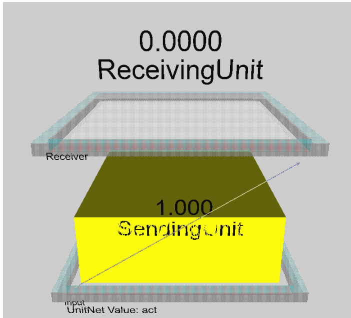

Figure 18: Visual representation of the sending and receiving units with g_{rev_e} at a value of 0.4.

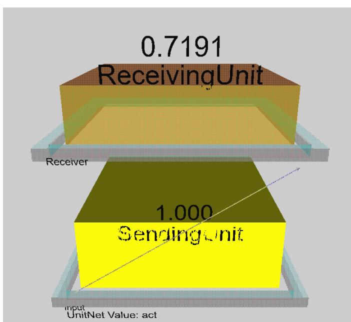

Figure 19: Visual representation of the sending and receiving units with g_{rev_e} at a value of 1.22.

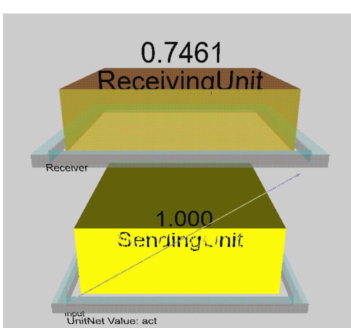

Figure 20: Visual representation of the sending and receiving units with g_{rev_e} at a value of 1.23.

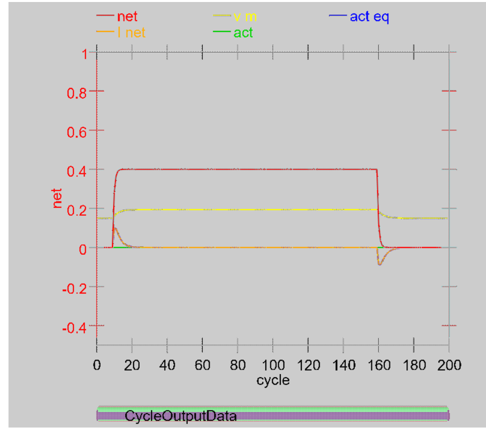

Figure 21: Graphical output data of fig. 18 when running a value of 0.4 for g_{rev_e}.

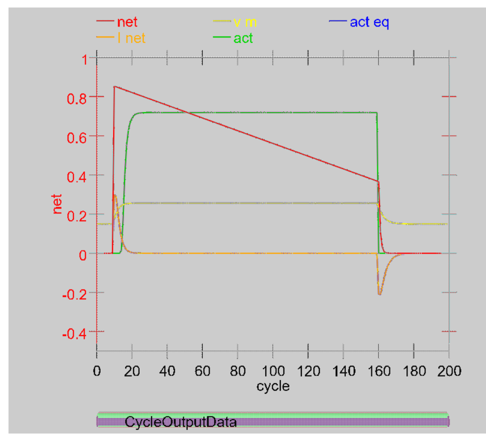

Figure 22: Graphical output data of fig. 19 when running a value of 1.22 for g_{rev_e}.

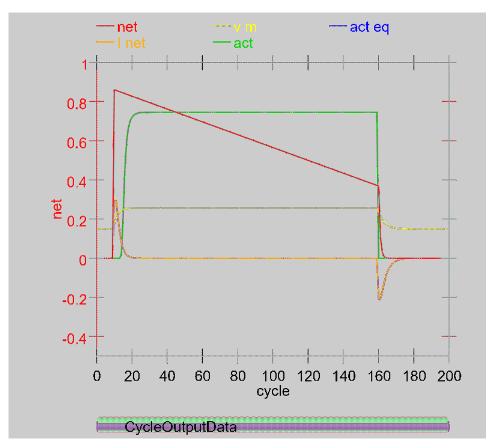

Figure 23: Graphical output data of fig. 20 when running a value of 1.23 for g_{rev_e}.

2.2 Q2: Exploration 2.6.3 (Page 55)

2.2.1 Task 2.7

Question 2.7 (a) *For each digit, report the number of input units where there is a weight of 1 and the input unit is also active. This should be easily visually perceptible in the display. You should find some variability in these numbers across the digits.* ***(b)*** *Why does the activation value of the receiving unit not reflect any of this variability?* ***(c)*** *What would be a better variable to examine in order to view this underlying variability, and why? [Mark: 10]*

In table 2 is the tabulated data record from the Emergent software. The data presented is the input data that is given to the receiving unit in the form of input patterns that display as digits from 0 to 9. In each individual digit, there are specific input data that activate it as seen in fig. 25 by the yellow (lit) up squares, these connect and directly relate to the receiving unit as depicted by the yellow lines.

The reason behind the receiving unit only activating on the number 8 digit in because all 17 input points are connected to the receiving unit whereas for the other 9 digits only up to 80% of them are connected where the weights are easily distinguishable in fig. 25. A better value to examine would be the net values of e_{bar_l} as it alters the activation value of each input unit without changing the original excitatory conductance (e_{bar_e}).

Number of connected and active inputs for each individual digit.			
Digits	Connected (Weight of 1)	Active (Active Sensors)	Value of Receiving Unit
0	6	12	0.0000
1	6	13	0.0000
2	12	15	0.0000
3	13	15	0.0000
4	5	14	0.0000
5	14	16	0.0000
6	12	15	0.0000
7	6	11	0.0000
8	17	17	0.9500
9	12	15	0.0000

Table 2: Number of connected and active inputs for each individual digit.

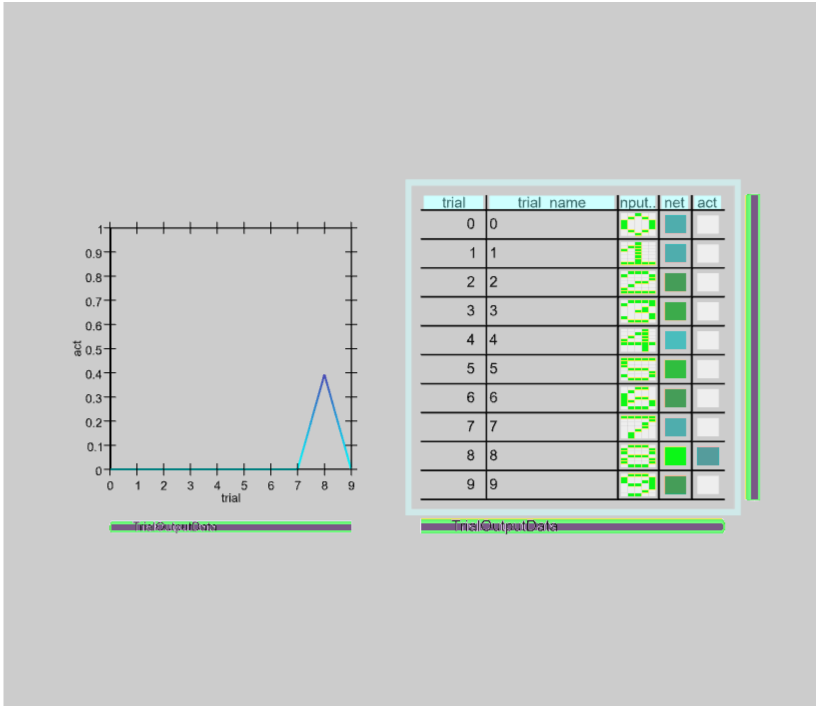

Figure 24: Graphical output of a full run cycle for this project.

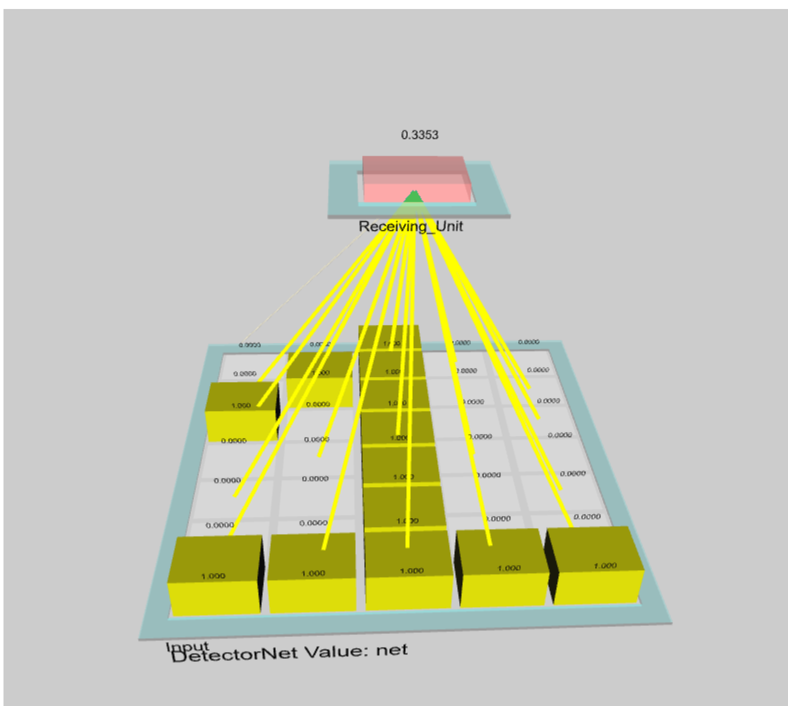

Figure 25: Visual representation of the connected data, input data and receiving unit.

2.2.2 Task 2.9

Question 2.9 (a) *What happens to the pattern of receiving unit activity when you reduce* g_{bar_l} *to 6?* ***(b)*** *What happens with* g_{bar_l} *values of 4, 1, and 8?* ***(c)*** *Explain the effect of changing* g_{bar_l} *in terms of the point neuron activation function.* ***(d)*** *What might the consequences of these different response patterns have for other units that might be listening to the output of this receiving unit? Try to give some possible advantages and disadvantages for both higher and lower values of* g_{bar_l}*. [Mark: 13]*

The default settings for the value of g_{bar_l} is 7, decreasing it to a value of 6 increases the activation value on the number 8 digit from 0.3930 to 0.9024. Changing the values of g_{bar_l} to 4, 1 and 8 are shown in table 3 for all the digits show a direct relationship between g_{bar_l} and the receiving unit. By changing the g_{bar_l}, the point neuron activation function changes in terms of the threshold and the change in g_{bar_l} changes the threshold allowing for the change in activation value. It's seen that as g_{bar_l} is decreased the activation value increases in the receiving unit and observing the value change in table 3 and it can also been seen that the lower values of g_{bar_l} allows for the surrounding units to copy in weight and as such allows the digits to activate the receiving unit. The higher the number the more accurate the weight is and therefore the number 8 digit is the only one that can activate the receiving unit so therefore the higher the value of g_{bar_l} the more accurate the weights of the individual units.

g_{bar_l}	No. 0	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9
7	0	0	0	0	0	0	0	0	8.3930	0
6	0	0	0.0033	0	0.1357	0	0	0	0.9024	0
4	0	0	0.9280	0.9478	0	0.9588	0.9280	0	0.9742	0.9280
1	0.9842	0.9842	0.9925	0.9929	0.9788	0.9932	0.9925	0.9842	0.9938	0.9925
8	0	0	0	0	0	0	0	0	0.0009	0

Table 3: Recieving values for individual digits with different g_{bar_l} values.

2.3 Q3: Exploration 3.4.2 (Page 87)

2.3.1 Task 3.7

Question 3.7 (a) *Given the pattern of weights, what is the minimal number of units that need to be clamped to produce pattern completion to the full 8? You can determine your answer by toggling off the units in the event pattern one-by-one until the network no longer produces the complete pattern when it is Run (don't forget to press Apply in the environment window after clicking).* ***(b)*** *The* g_{bar_l} *parameter can be altered to lower this minimal number. What value of this parameter allows completion with only one input active? [Mark: 6]*

With 17 units turned on, the pattern is a visible whereas when 18 units are active the the number

8 is not display at full, this is because due to only 17 units being connected to the receiving unit. g_{bar_l} can be changed from a value of 7 to 3 to which only one input is active.

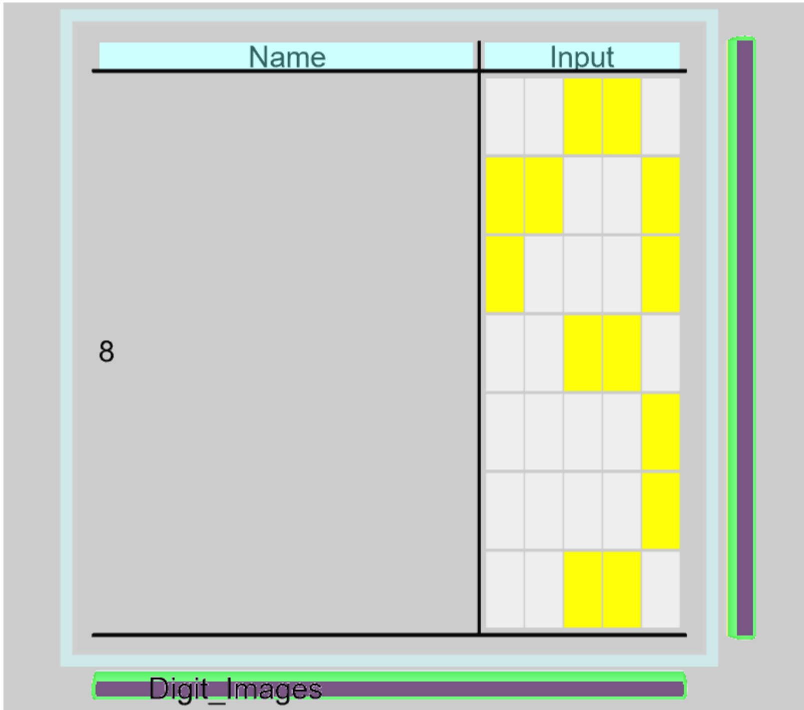

Figure 26: .

2.3.2 Task 3.8

Question 3.8 (a) *What happens if you activate only inputs which are not part of the 8 pattern? Why?* ***(b)*** *Could the weights in this layer be configured to support the representation of another pattern in addition to the 8 (such that this new pattern could be distinctly activated by a partial input), and do you think it would make a difference how similar this new pattern was to the 8 pattern? Explain your answer. [Mark: 7]*

When inputs are activated that aren't part of the number 8 digits pattern the image disappears because the weight values of the unit is equal 0. The new pattern could be the number 3 digits as shown in fig. 26 as enough input units are activated to produce the number 3 digit pattern as it uses the same pattern units as the number 8 digit minus a few units.

3 Further Questions

3.1 Further Question 1

Why are the O'Reilly and Munakata equations called point neuron equations? As a consequence of this, what aspects of neurophysiology can these equations not reflect?[Mark: 6]

3.2 Further Question 2

In the output activation equation below, what would the consequence be of replacing the +1 term with +10? How could one obtain a similar effect by changing a parameter of this equation? [Mark: 7]

$$y_j = \frac{\gamma[V_m - \Theta]_+}{\gamma[V_m - \Theta]_+ + 1} \tag{7}$$

By plotting the rate code output function above and using V_m as the unknown variable where γ and Θ are fixed variables, it's seen that by increasing the denominator from +1 to +10, the output activation value (y_j) decreases in value as when compared to +1.