BT6270 – Computational Neuroscience
Assignment 2

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Introduction

FitzHugh-Nagumo neuron model is mathematical model that simplifies the Hodgkin-Huxley model. This assignment was aimed at using forward Euler Method, to obtain phase plots, value of external applied current, where the voltage oscillations were observed, and finding stable, unstable, saddle points and limit cycles.

Method & Observation

We used MATLAB to write the code to execute the tasks given.

Case 1:

- Values of a, b, r were taken to be 0.5, 0.1 and 0.1 respectively.
- Phase plot was obtained using the v-nullcline and w-nullcline.
- The differential equations were solved using forward euler method, with 5,00,000 iterations.

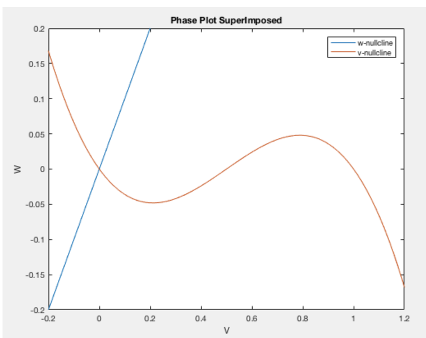

Fig1. Phase Plot

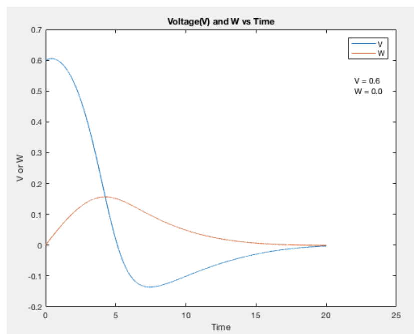

Fig2. V and W vs Time

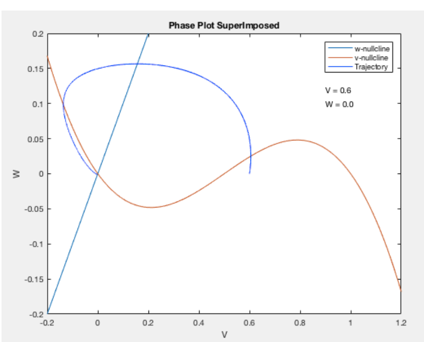

Fig3. Phase Plot with trajectory @ v = 0.6

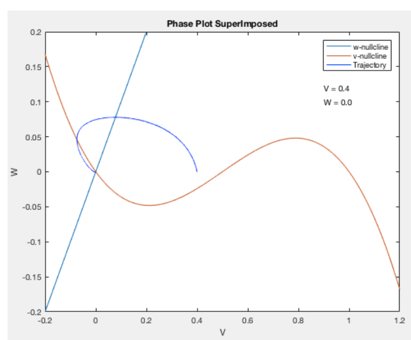

Fig4. Phase Plot with trajectory @ v = 0.4

Case 2:

- Oscillations for External applied current (Iext) was ranging from 0 to 1 mA were obtained.
- Oscillations with peak values greater than 0.5 was considered, and I1 and I2 were obtained.
- For Iext = (I1 + I2)/2, phase plot was obtained, along with the trajectory to check if the point is stable or unstable

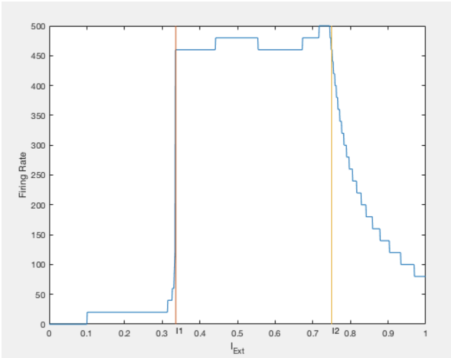

Fig5. Firing rate vs Iext

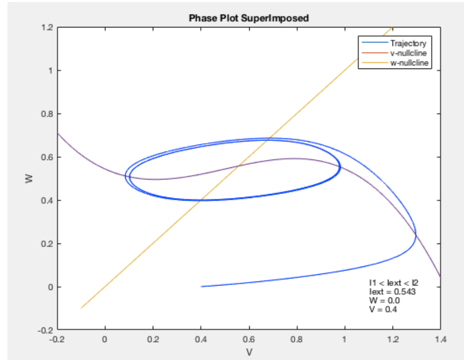

Fig6. Phase Plot with Trajectory @ v=0.4, w = 0, I1 < Iext < I2, limit cycle

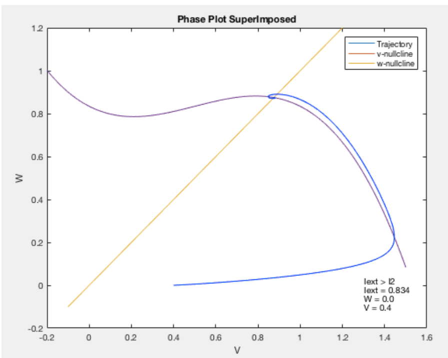

Fig7. Phase Plot with Trajectory @ v=0.4, w=0, Iext > I2

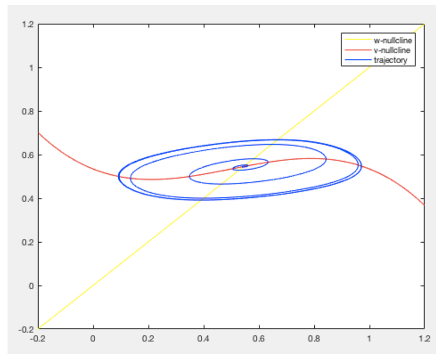

Fig8.Phase plot with Trajectory @ v = w = 0.543 + 0.0001, stable point

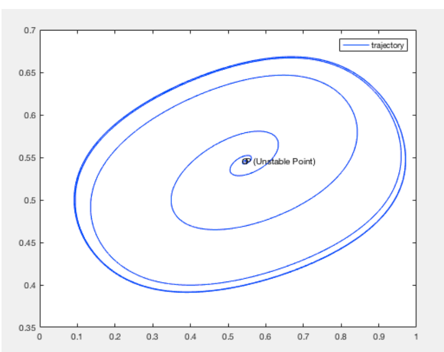

Fig9. Trajectory @ v=w= 0.053 +0001

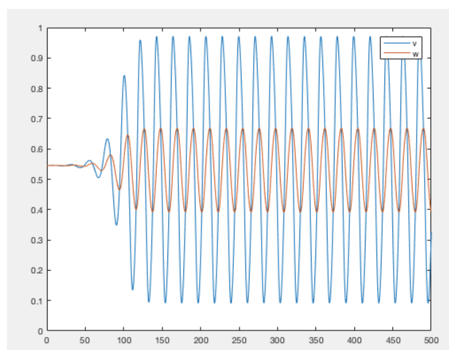

Fig10. V and W vs Time @ v = w = 0.053 + 0.0001

Results:

The value of I1 and I2 were evaluated to be 0.336 and 0.75 mA respectively. Limit cycle was observed in the Fig8 and Fig9, showing that the point is unstable.

Case 3:

- Iext = I2 + I1/4 was used to get the phase plot
- Small pertubrations were made to check if the point is stable or unstable

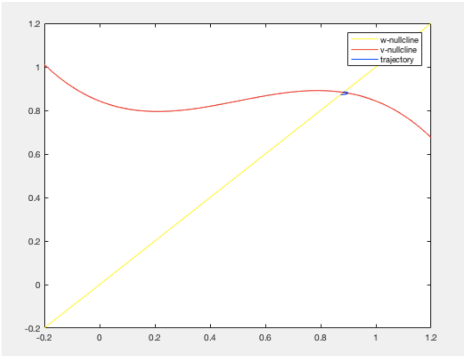

Fig11. Phase Plot with trajectory @ v=w=0.843 + 0.001

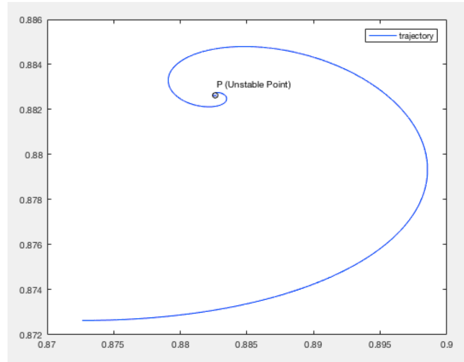

Fig12. Trajectory close-up @ v = w = 0.843 +0.001, stable point

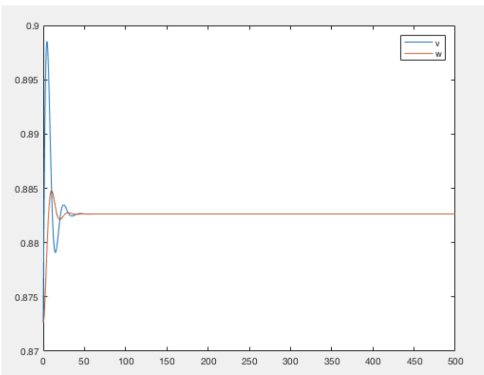

Fig13. V and W vs Time @ v=w=0.843 + 0.001

Case 4:

- Values of a, r and b were optimized to get the bi-stability.
- a = 0.5, r = 0.8, b = 0.01, Iext = 0.02 was used to obtained the following curves.
- So, b/r = 0.00125 and Iext = 0.02 are the values for which the bistability was observed

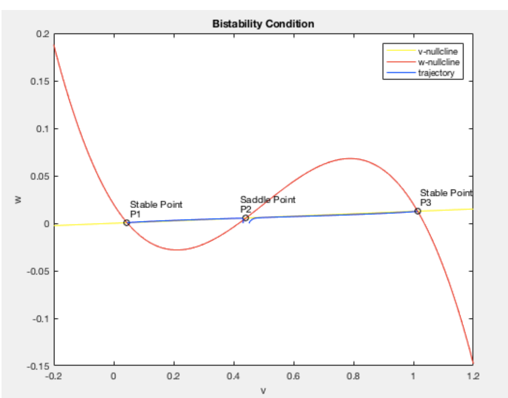

Fig14. Phase Plot with trajectory @v = 0.4413 +/- 0.01, w = 0.0055

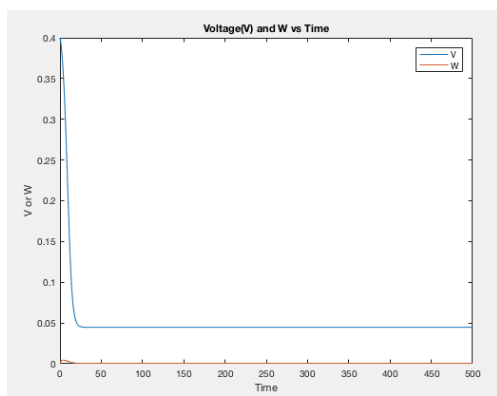

Fig15. V and W vs Time @ V = 0.4, w = 0

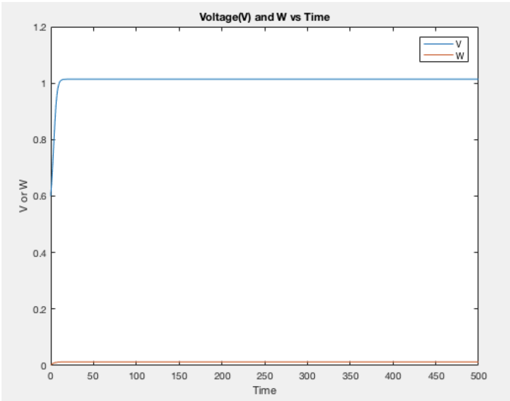

Fig16. V and W vs Time @ V = 0.6, w = 0

Results & Conclusion

FitzHugh-Nagumo neuron model was found to be simple yet effective neuron model compared to Hodgkin –Huxley model. All the important features of the neuron firings are preserved such as oscillation, limit cycle etc. Reduced number of differential equations (2 in this case) make it easy to model, at the same time are computationally inexpensive.