Analysis of hippocampal data

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Abstract— **This report explains the various results analyzed from the real data, which contain the information about the four hippocampal neurons of a rat while it was running in a maze.**

I. INTRODUCTION

This assignment focuses on the analysis of the characteristics and behavior of hippocampus by understanding the relationship and nature of spiking in different regions within it. The two main regions within hippocampus are *Cornu Ammonis(CA) and Dentate Gyrus(DG)*. CA is further divided into 4 regions CA1-CA4 and *Entorhinal Cortex(EC)* is the main input to the hippocampus. These different sections of hippocampus are connected to each other in a special way. EC is connected to DG, CA3 and CA1 through axons called perforant pathway. Mossy fibers run from DG to CA3 and Schaffer collateral fibers go from CA3 to CA1.

Hippocampus are believed to play an important role in memory and constructing spatial maps. To analyze this, we will be using a real data of 4 hippocampal neuron. This data was collected while a rat was running in a maze [1]. The rat was trained for a better run through the maze prior to electrode implantation. Rat starts at a reward point (F1 or F2) and runs toward the central arm of the maze(stage 1 in Fig. 1). A movable barrier directs the rats to the central arm and then to the choice point(stage 2), where the rat can choose between turning left or right. The rat should go to the C1 if it starts from F1 and C2 if it starts at C2. If the correct turn is made (stage 3) a chocolate reward are made at C1 or C2. Rat then turn to the choice point (stage 4) and further directed to the central arm (stage 5) by a movable barrier. The barrier directs it to a reward point at F1 or F2 (stage 6), with left or right turns selected at random from trial to trial. All these movement of the rat can be seen in an animation submitted with the report Fig. 2

Stages 1 and 2 presumably invoked spatial working-memory processes. Rats were required to remember the path of C1 or C2 to get to the reward. By stage 3, their decision had already been made, and any further use of working memory is not required. Stages 46, which were forced turns, never required active working memory, since routes back to F1 or F2 were always performed by the barriers.

Different sections in this report explains the different visual outcome achieved using the data of 4 hippocampal neurons.

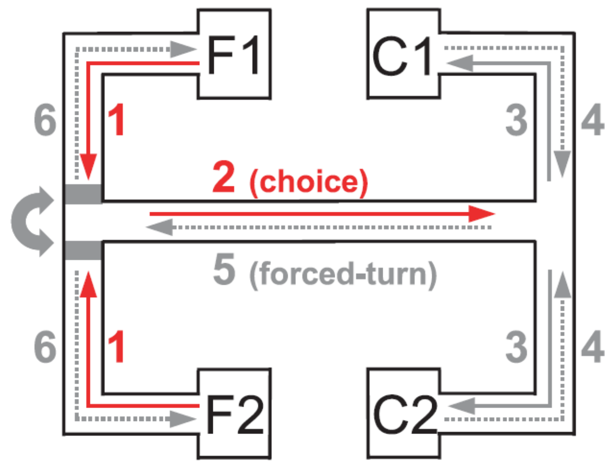

Fig. 1: Different behavior stages of the rat in the maze [1].

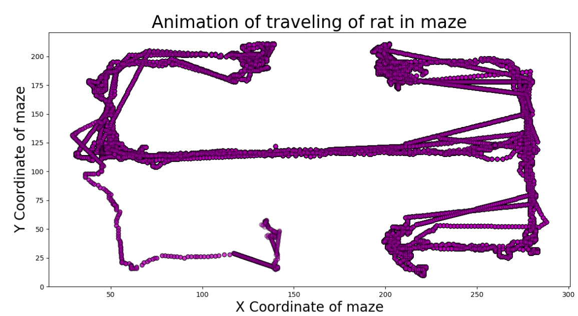

Fig. 2: Screenshot from the animated movement of the real rat.

II. FIRING POSITION OF NEURON

This section explains about the position in the maze where each neuron fired a spike. To achieve this, we are using a data which is in .csv format. We are provided with 6 files: time, x, y, neuron1, neuron2, neuron3, neuron4. Time file contains the value of time in 1/10000 of a second, when the position of the rat was measured. X and Y files contain the position of the rat in above moments of time and files neuron1, neuron2, neuron3, neuron4 contain the time when neuron fired a spike.

To analyze the position of neuron spike, each value in neuron file was searched in time file. If the time file contains it, value in x and y file on same index are stored in an array.

This gives the position of the rat in the maze at that point of time. In case, if the time file does not contain the value of neuron spike time, the nearest value within time file is taken and position is determined. This techniq ue was approached as time file does not contain all the instances where a neuron fired a spike.

Position of each neuron spike is obtained by following procedure discussed in above paragraph. We get the position denoted by a colored circle as seen in Fig. 3. Labeled four different colors denote the 4 different neurons. Although it makes it congested, but spikes of all the neuron are depicted in the same figure as it enables us to do a comparison. The circles are made a bit transparent to get a better view. Apart from it, data of different neurons are depicted optimally by choosing a better order of overlapping.

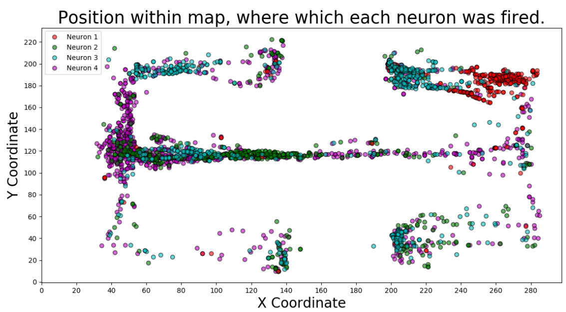

Fig. 3: Spiking position of different neurons in the maze.

Neuron 1 are depicted in red colored circles. These neurons are fired mostly in the top right corner of the maze. This position is close to the C1 i.e. the position where the rat gets a chocolate as reward if it gets here after starting from F1. F1 and C1 contains the greater number of fired neuron as compared to F2 and C2, so lets assume that the rat started from F1 for most of the time and hence got a reward. In this case neuron 1 are fired when the rat is close to the reward. Neuron 2 denoted in green is fired most when the rat was forced to turn into the central arm. Neuron 3 in blue color fired at C1, C2, close to F1 and the position where rat was forced to turn to central arm. This denotes the position where a turn is to be made. Neuron 3 has a high concentration at C1. Neuron 4 shown in magenta colored circle was active throughout the maze, but was fired a lot more times at stage 2 and 6.

III. AUTO-CORRELOGRAMS AND CROSS-CORRELOGRAMS

This section will explain the auto correlation of neurons. Autocorrelation is a representation of the degree of similarity between a given time series and a lagged version of itself over successive time interval.

Auto-correlogram is the representation of self correlation and can be achieved by using a function called correlate in *NumPy* library [2]. If we directly use it on the neural data, we get a congested wave like structure, which is hard to understand. Therefore all the values of neuron data were subtracted by the mean value of the neuron. The correlation results were obtained and were divided by the maximum value of correlated data. This gives us a graph which is easier to understand.

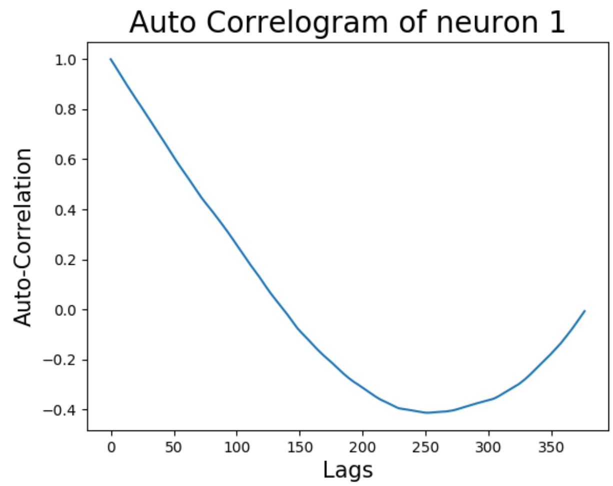

Fig. 4: Auto-correlogram of neuron 1.

Fig. 4 and Fig. 5 shows the auto correlogram of neuron 1 and neuron 4. The correlation of both the neurons decrease from 1 to -4 regularly with time lag and then increase again to 0. This pattern is same for all the neurons.

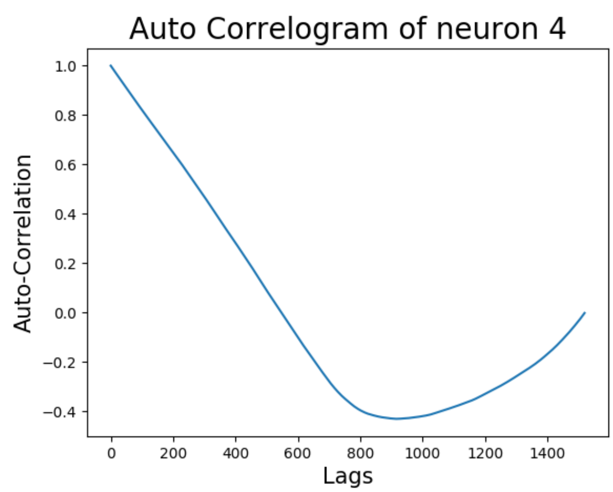

Fig. 5: Auto-correlogram of neuron 4.

Cross-correlogram explain the correlation between 2 different neurons. Same configuration was used as for auto-correlogram to find cross-correlogram, except using two different neurons instead of same. Correlation was found for every pair of neuron. Neuron 1-4 Fig. 6 are correlated more than 1-2. Apart from 1-4, neuron 1-3, 3-4 were also correlated better than the other pairs.

IV. FIRING RATE OF NEURONS

Firing rate of the neuron is the number of times a neuron fire a spike within 1 second. The time of the neuron spike

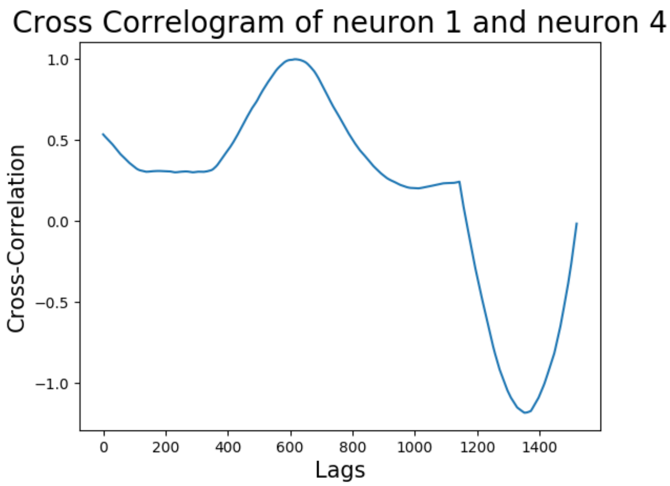

Fig. 6: Cross-correlogram of neuron 1 and neuron 4.

in data available is given in 1/10000 of a second. So, the data of both neuron and time file was converted to seconds. The number of times the value in neuron file repeated post conversion to the second denoted the firing rate.

Firing rate was depicted using 2 graphs: histogram and wave plot. On one hand, where histogram Fig. 7 explains the number of neuron that have same firing rate, wave plot explains the firing rate of neuron for every second. The firing rate of the neuron 4 for the time interval 3198 sec - 4286 sec can be seen as wave plot in Fig. 8.

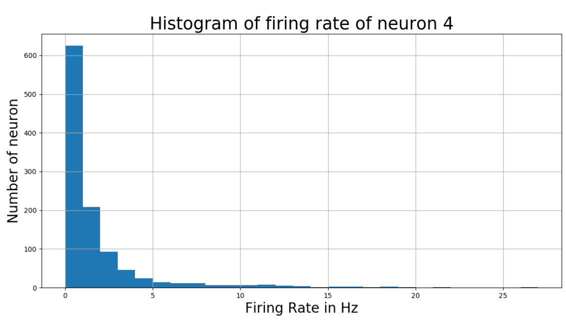

Fig. 7: Histogram for firing rate of neuron 4.

For all the neurons, firing rate of 1 is most common, specially for neuron 2 and neuron 3. So, most of the time a single spike is observed in one second. But the highest firing rate range from 8 for neuron 2 and 3 to more than 26 for neuron 4. Neuron 4 also sees the most number of spikes and neuron 2 the least.

V. Firing Rate of Different Sections of Maze

Firing rates of individual neurons in different part of the maze was achieved by dividing the maze manually into 5 different regions: left upper(F1), right upper(C1), left down(F2), right down(C2) and the central arm. The firing

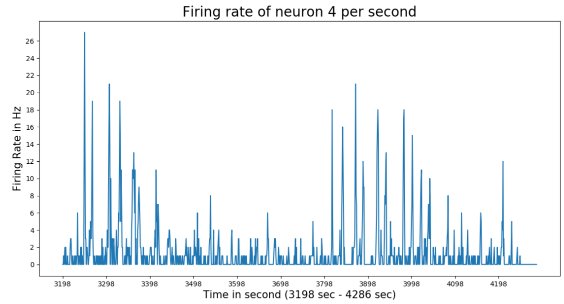

Fig. 8: Firing rate of neuron 4 for every second.

rate of neuron at different region is calculated similar to the question 4.

It can be seen from Fig. 9 that the central arm has the most number of the spikes that are being fired by the neuron. Even the highest firing rate is also observed in the central arm, which is greater than 26. This firing of neural spike happens close to the point where the rat was diverted towards the central arm using a barrier and than when the rate makes a choice to turn.

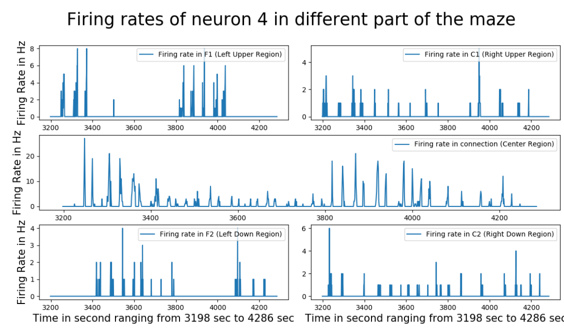

Fig. 9: Firing rate each neuron at different region of the maze.

References

[1] Matthew W. Jones & Matthew A. Wilson, Theta rhythms coordinate hippocampal-prefrontal interactions in a spatial memory task, PLoS Biology, 3nd ed. vol. 12, 2005, pp. 2187-2199.

[2] ”Numpy python library home page”, http://www.numpy.org.