Computational Neuroscience
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Week – 08
Lecture – 37

Lecture 37: Single Cell Deocoding - I: Two Alternative Forced Choice task in Monkeys

Welcome. So, we have been discussing some of the statistical methods applied to discrimination studies. We discussed about primarily Fisher information and minimum variance unbiased estimator discussions and the relation between the I mean the minimum variance unbiased estimator and Fisher information which is the Cramer-Rao bound. With that we discussed on fidelity of coding by neurons based on this Fisher information and it is a function of the stimulus and the Fisher information shows how the discrimination performance would be near that very value of s or the stimulus and that is if we change the s in a very small amount then how well can we discriminate them. So, as we had discussed in mutual information early on and in some other discussions we were considering that the stimulus is not necessarily going to be that parametric and that there will be a very small difference, but there can be many different entities as we did for the confusion matrix. Now, we will take up an example where we will try to relate discrimination of two stimuli and try to relate it to performance by a subject in that in this case it is a trained monkey that is doing the discrimination task and the neurons in its cortical region that is thought to be involved in processing such stimuli.

The performance based on the neurons will be compared with the actual performance of the monkey and see how well it matches and at the end there we will have a small discussion about the perturbation studies where more about the causality can be established. So this is work by Britton et al. It is now about 30 years old, 1992. So in this case the area of the brain that has been studied is the area called MT which is in the where visual pathway.

If you recollect from our early discussions on the different sensory systems we had that in the visual system after the initial stages in the cortical region the visual pathway is divided into two parts. One that processes what information and goes on to do object recognition and the other that goes on to process the location or position information and goes on to the more on the dorsal side of the cortex. Now this area MT is known to be the neurons in there are known to be direction selective that is within the receptive fields of neurons that is if we have the somewhere the visual field like this if this represents the entire visual field then the actually the receptive fields are quite large and if there is motion of a visual object in there then the neurons here respond strongly to one particular direction and less strongly in the other directions with a minimal response or even suppress response in the direction opposite to its preferred direction. So if we have object movement in the field of view along different directions this theta varies from 0 to 2 pi or 360 degrees then if we plot the response rates and this is our angle theta direction of motion and this is rate then neurons have a preferred direction that is some theta naught to which the response rate is maximum and in the exactly opposite direction that is theta naught plus pi it has sort of a minimal response. So this is the opposite direction theta naught plus pi in fact there may not be responses and sometimes it may even dip below its spontaneous level.

So we have now the response characteristics of the neurons that we will be discussing that they are selective to direction of motion. Now as we have said all along these responses are stochastic in nature and generally follow a Poisson like distribution in terms of spike counts. So the this curve that we have plotted this tuning to movement direction that is based on average of many many repetitions. So in general if I take a particular direction be it the preferred direction which is theta naught there is a large degree of variability in response large I mean it depends on the kind of neuron and so on there is a variability around that region. So that means the rates can be scattered around this region and the average is like this.

So now if we take the histogram of the rates at a particular direction then let us say this is rate and this is percentage of trials. So let us say if we present it 20, 30 or 50 or 100 times that moving stimulus in that theta naught direction then we can get different possible firing rates and that may have a distribution which is something like this where this is our mean rate. And this is being so if this is the response distribution for the angle theta naught this mean rate is what is being plotted here. So this this rate mean rate is what is the mean rate here in the tuning curve. So we have a spread around that mean rate.

So if we are tasked with the job of discriminating two different directions then we will let us say if it is theta prime here theta naught or let us say theta 1 these two there is a distribution of rates around that also and so that rate may be here and there may be a distribution of responses around it. So as we have seen so the task is then to make the decision about whether the two stimuli are different or not depends on the actual spread of these rates for that neuron or the population of neurons. So we will currently limit the discussion to a single neuron but can easily be extended to population of neurons. So given this spread we can have an overlapping region and so the obviously the more separated with lesser spread these distributions are we will get better performance in terms of discriminating two different directions of motion. So this this here we are considering theta naught as the as a continuous sort of variable just as we discussed in Fisher information.

In the example that we will talk about it will be about specific two directions only which is the neurons preferred direction theta naught and the orthogonal sorry the opposite direction theta naught plus pi modulo 2 pi. So now to so since the this is an experiment with monkeys the task was made in this manner to simulate direction of motion a random dot pattern a random dot pattern stimulus was used. So what is this random dot pattern? So in the receptive field of the neuron within that region there are a number of dots at random positions within that region and so the dots all can move in one particular direction all of them. So that move as in the image or the video in every frame is updated in this manner that is every 45 milliseconds. So the image that is shown here with the random dots are present for 45 milliseconds and immediately after that the there is an updated position of the dots which is a small movement in a particular direction.

So all of them shift in a particular direction like this. So the new pattern is by this and there may be some new dots coming into the field of view or in the receptive field to have a continuity. So if you can now imagine that in the next instant they move again in that same direction that would mean that there is a motion in the field of view of the monkey and so this will clearly have the effect of a motion within the receptive field. And so the first the direction tuning or rather the movement direction tuning of these neurons are obtained. So we have the theta naught and the theta naught plus pi modulo 2 pi.

We can drop that modulo basically you understand that preferred direction and the direction opposite to it. So in this case when all the dots are moving in the same direction together it is and all the dots are moving in the opposite direction together the monkey which has the task to discriminate these two can easily do the task. So what we mean in this case is that when all the dots are moving in sync all dots are moving in sync that is every that is just as we talked about all of them are moving in the same direction together that is what we call a 100

Then as we reduce this coherence to 30 to 20 and in fact to 1 and then to 0 which means the 0 case is that there is no direction of motion actually that is the dots are updated in totally random directions every time. So $theta_0$ and $theta_0 + pi$ have no meaning and so it is impossible for the I mean impossible for the monkey in a two alternative force choice to do anything correctly. So it will 50

So as we said when the coherence is 0 or extremely small let us say we will have this logarithmically let us say it is 0.01

So the performance would start out as we said at a 50

So this function the percentage correct as a function as a function of percentage coherence this is the behavioral or psychometric function that is this is what the monkey is actually doing in terms of its behavior how well it is performing for the different coherence levels. So now in order to actually perform the analysis we if we consider the responses at different coherences what is observed is that for 100

Similarly as we go to 0

So we essentially have something like the confusion matrix that we had discussed earlier and so and we will call this box here is the hit rate that is we will represent by the symbol beta. What we mean by that is what is the probability of correct if the stimulus is a plus stimulus that is probability correct given plus and we will call so obviously the probability of incorrect is going to be 1 minus beta that is probability of incorrect given the plus stimulus. Now when the stimulus given is minus if the probability of incorrect when the stimulus is minus that means we are saying based on the responses we are saying that there is a plus stimulus although there is a minus stimulus that is what we mean by incorrect with the minus stimulus and that is called the false alarm that is we are falsely saying that the positive stimulus has occurred. So this will be represented by alpha and obviously this is going to be 1 minus alpha given the different stimuli. Now if we assume that these stimuli have equal likely equal probability of occurrence this is half and half we will get a joint distribution by simply dividing each of these values by 2.

So this is going to be our beta which is hit and probability of incorrect given the minus stimulus is our alpha. So what are we basing our decisions on that well I mean we take the call that it is a plus stimulus based on the responses or we take the call it is a minus stimulus based on the responses we have to define something called a threshold here and that threshold would be somewhere in between the overlapping region and we can call that Z. So we have rate distribution here we will consider it continuous as we have always said the spike count is discrete but if we randomize the duration over which we are calculating the rate then it also becomes a continuous distribution. So probability of correct given plus is beta is going to be a function of this threshold that is if we choose that threshold to be Z if the rates are larger than Z then we call that the stimulus is plus. If we have rates that is less than Z then we call the stimulus is minus.

So if this is our criteria for decision making then these betas and alphas are going to be a function of Z depending on where I put this threshold. The threshold can be put here the threshold may be put here depending on that. So this is Z and we can also then bring in the rate as random variable that is $beta_Z$ is probability that our rate is greater than equal to Z given a plus stimulus and similarly $alpha_Z$ is going to be the probability that R is greater than equal to Z given a minus stimulus. So this is hit and this is false alarm. So we will now see how to analyze this is to use what we call the ROC curve or receiver operating characteristics.

So in that what we will see is basically a plot of our alpha and beta as a function of Z alpha as a function of Z. So alpha and beta are going to be what we have said the hit and false alarm and so since they are probabilities they would range between 0 to 1 and here also 0 to 1. And for varying Z we will have different kinds of performances or different kinds of alpha and Z which is what we call the receiver operating characteristics analysis. So we will stop here in this lecture and we will start off with analyzing the receiver operating characteristics the ROC curve in the next lecture. Thank you.