Neural Science for Engineers
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Module - 02
Lecture - 10
Spatial and Temporal Summation of neuronal electrical activities

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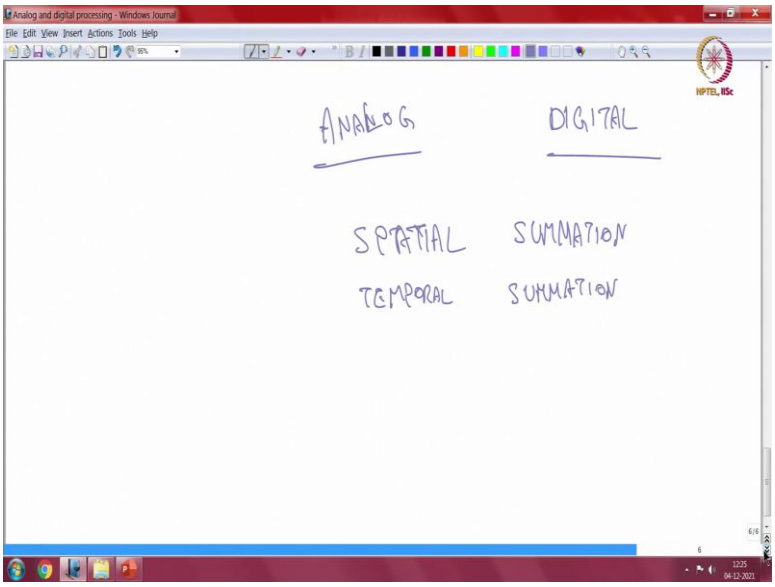

So, previously I have discussed something about how analog computing and digital computing happens within a single neuron. So, this the discussion was in a single neuron. But there are some technical terminologies, which I would be to see in biological terms it is called as spatial summation and temporal summation ok, graphs again.

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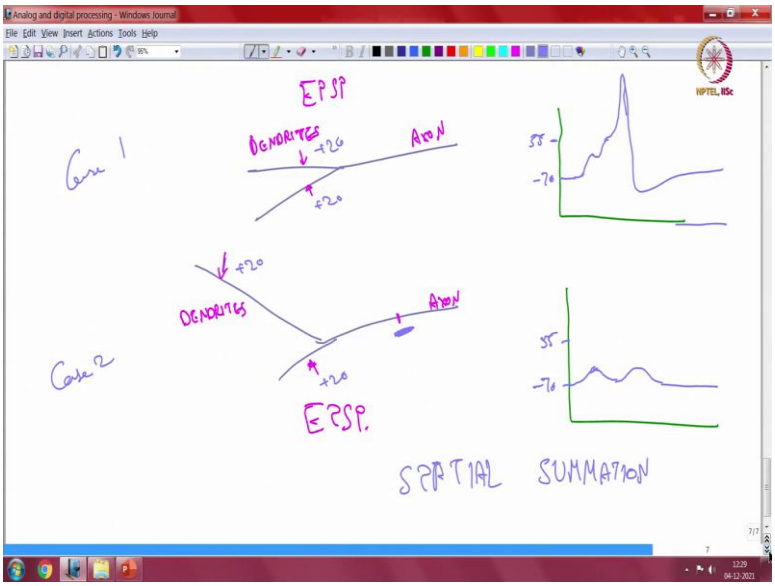

So, spatial summation is simple; so simple in the sense that you have signal here, signal here, measurement here. So, when you have signal here, signal here, we assume that both of them are positive, and we assume that what are EPSP. So, we need to clarify that EPSP, and then this is the axon, these are dendrites. So, axon-axon, dendrite-dendrite, and how stimulus differs with both.

So, in the first case, you have a signal coming through -70. So, you need -55 which is the threshold for activation potential. I will start with the second graph because the first graph is pretty obvious -70, 55. So, both of these are EPSP. So, EPSP what happens to them, what happens to the axon and if in case 2 , case 1.

So, in this the first signal which is the EPSP over here which is the small current which is generated over here. It does not reach the threshold required for activation; we will label it as around +20. So, then there is a 20 which happens because this is closer, then it comes down. The subsequent 20 comes at a later point of time.

So, you have only two, two small EPSPs which have changed when there is no action potential which is generated in the axon, no signal gets transmitted. Same two EPSPs which are here. So, the first EPSP is generated, and it comes up over here. So, and the second EPSP reaches up to 55, and that in turn triggers an action potential. So this is the idea of spatial summation. Spatial summation is summation over space.

Somehow nowhere in computer architecture from semiconductor design, VLSI design to neural network design is the concept of space incorporated from all the diagrams, which I have seen in terms of circuit diagrams, or ANN designs. The idea of incorporating space or distance as a method of computing somehow does not exist. Everything is paper based two-dimensional and has a very two dimensional problem to the whole of the engineering side.

The nervous system in this is you know I have just drawn line diagrams. And I am pretty sure somebody would be inspired to work it out in greater detail as to the richness of incorporating space is a space is a hyper parameter. So, space would give entire new dimension to a lot of electrical, electronic design and maybe even neural networks. See neural networks are still designed on paper.

You have two-dimensional neural networks which are built, convolutional neural networks of course use channels, but essentially the computational thought is two-dimensional. It is not even a neural network, this is one single neuron which we have been discussing so far. A single neuron uses space as a method of computation, richly analog and generates these kinds of differing graphs which is obviously information processing. This is about spatial summation.

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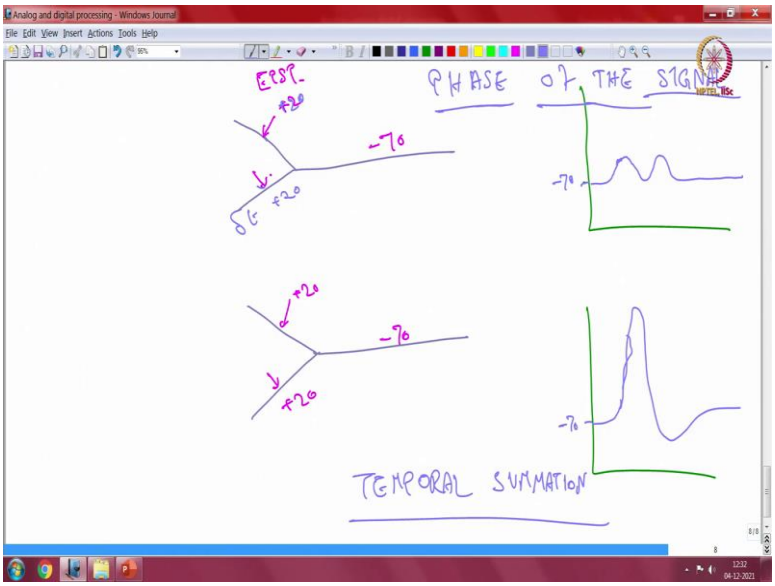

We will go into the next one with the same logic to explain temporal summation. So, temporal summation is little easier to explain. So, stimulus here is at similar points EPSP

again. So, it is a +20 and this is also a +20, but there is a time delay for this stimulus over here. And here again you have +20 and +20, 40, 70, -40 is +30, so -70, -70, and we draw the graphs -70.

So, what happens you have your first 20 coming up sometime, and then there is a delay for the other 20 to come, and so that does not cause anything and then there is a straight line. Here you have -70. Both come at the same time, and it produces a single action potential, so spatial summation.

This is temporal summation. This is biological theory. So, basically what temporal summation is discussing about is phase of the signals, how phase integration is useful for information processing and that is the notion of spatial and temporal. Spatial is because two things are separated by a distance.

Both of them start at the same time but arrive at different times because of the spatial separation. In terms of when it is in both of course, logically yeah there may be somebody who would argue that ultimately it is the same and that is why we have been so brilliant that we put everything on two dimensions and work out that is one way of looking at it.

But spatial computing is a very unique property, it is a three-dimensional rather than four-dimensional computing which the other system does, three dimensions and one in time. So, four-dimensional computing and analog ionic computing which is done in our system to do various kinds of information processing.

So, in the past couple of minutes what I have discussed is how same digital signals get converted into analog. So, you have unitary quanta of vesicles delivered by unitary action potentials into dendrites, but just differ in either space or length of travel. They produce different outputs and how it is feasible is shown over here.

The technical terminology is different, but I think the understanding which has to go is how these two are very powerful concepts, which the nervous system has harnessed to do its rich information processing. Also, a hidden message or a very obvious message to people who are interested in the discussion to continue this work and explore new possibilities in semiconductor to ANN CNN research.

Thank you.