Computational Neuroscience: Neuronal Dynamics of Cognition

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

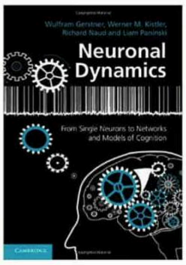
Neuronal Populations

Wulfram Gerstner

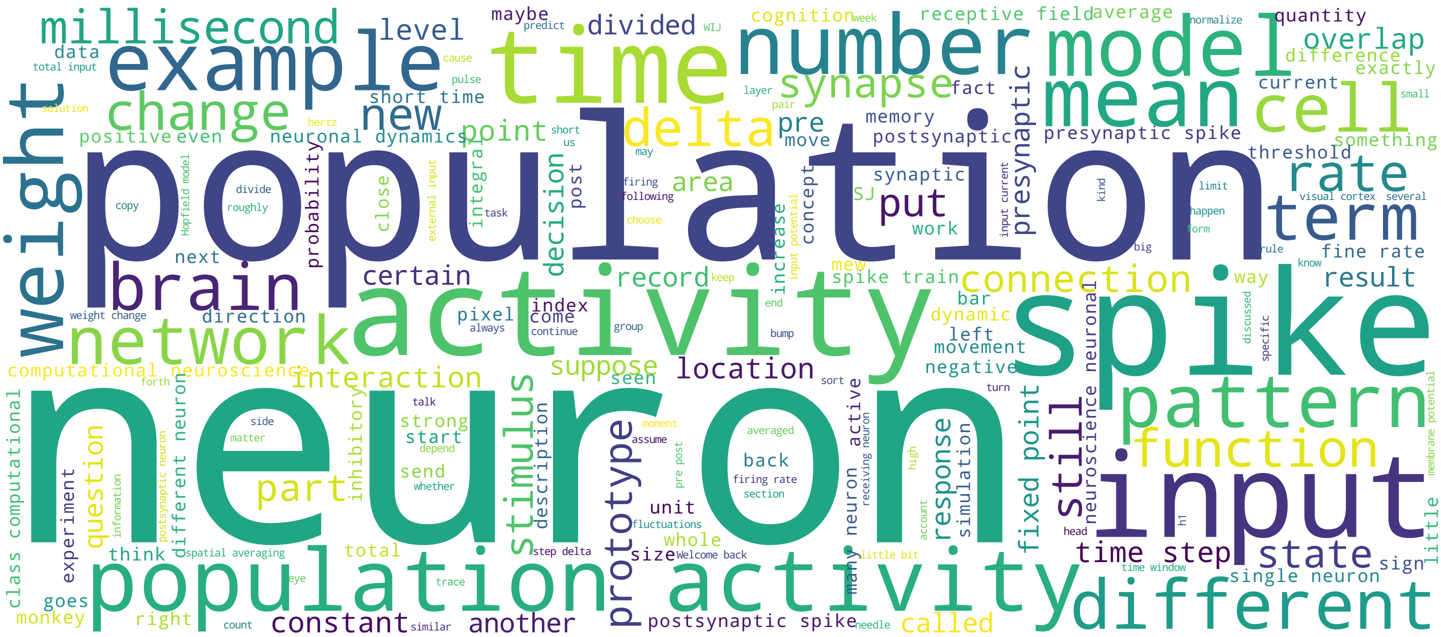
EPFL, Lausanne, Switzerland

Reading:
NEURONAL DYNAMICS
- Ch. 12.1 – 12.4.3
(except Section 12.3.7)

Cambridge Univ. Press



1. **Population activity**
   - definition and aims
2. **Cortical Populations**
   - columns and receptive fields
3. **Connectivity**
   - cortical connectivity
   - model connectivity schemes
4. **Mean-field argument**
   - input to one neuron
5. **Stationary mean-field**
   - asynchronous state: predict activity
6. **Random Networks**
   - Balanced state

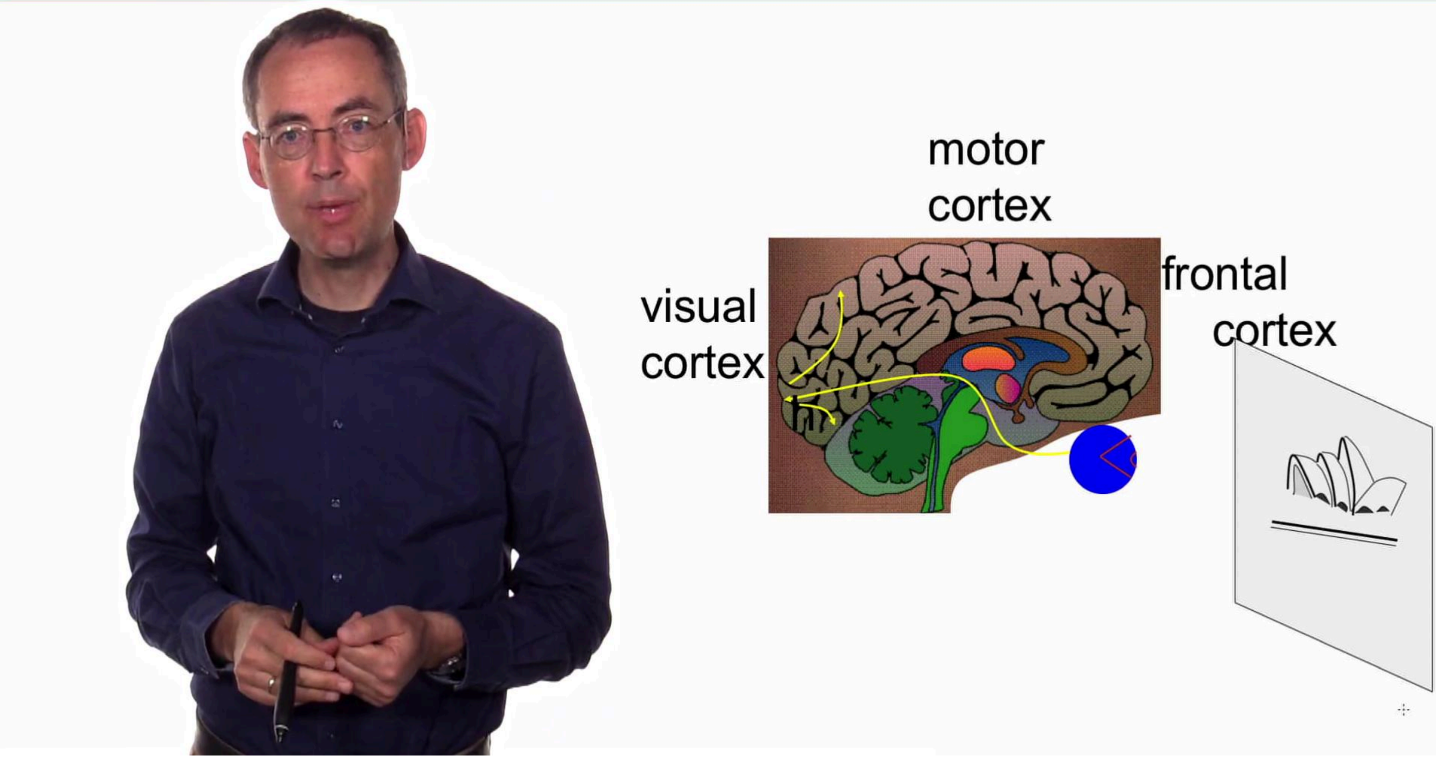


Search MOOC

Video

EPFL

1. review: the brain



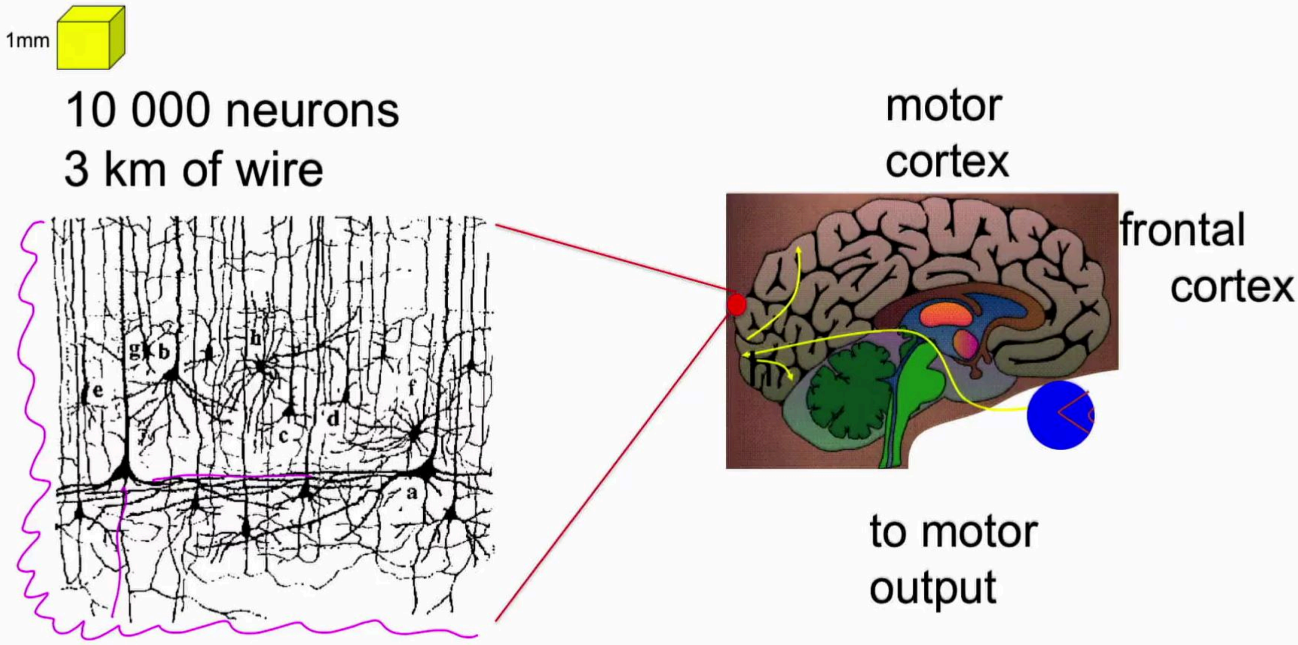
Welcome to the class, computational neuroscience: neuronal dynamics of cognition. The brain is this fascinating material that we have in our head, it's organized in different areas suppose you watch a movie. So information would enter through the eyes. Go to the back of the head in an area that's called visual cortex, and from there it was spread out to other areas. Now this is a course description of the brain.

Notes

Summary

0m 05s

1. review: the brain

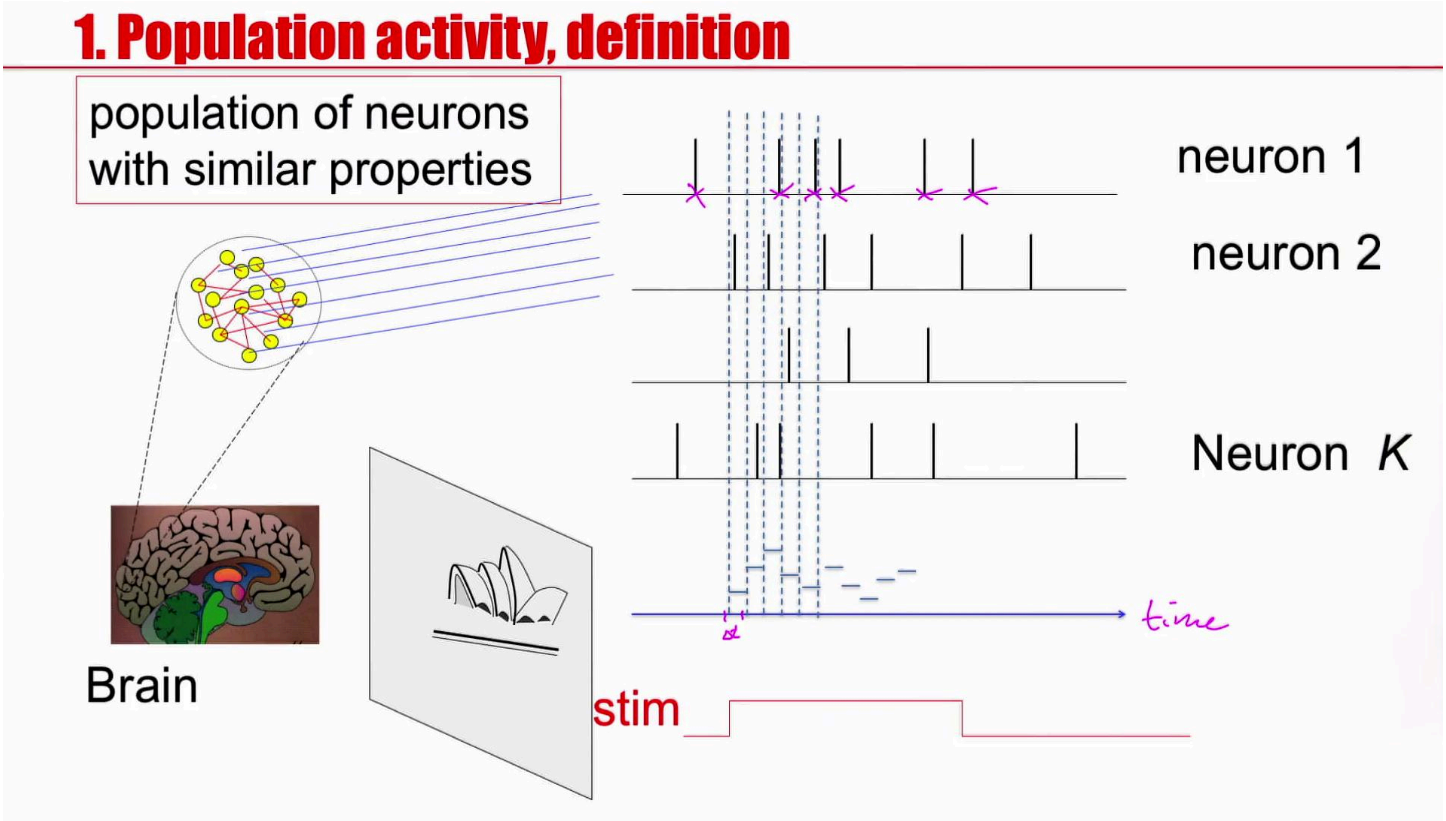


You can also zoom in. If you zoom in and put a tiny bit of brain material under microscope, you would see a highly organized and highly complicated network of cells, and these cells have these long wire like extensions. So in each cubic millimeter, you would have about 10,000 neurons or more. And if you just put all these wires together, we would have three kilometers of wire. So it's a densely connected network of neurons, a dense network of cells, and the neural network. And if I have 10,000 neurons in a cubic millimeter you can imagine that they have lots of neurons billions of neurons tend to the 10 neurons in the whole brain. This is a lot.

Notes

Summary

0m 26s

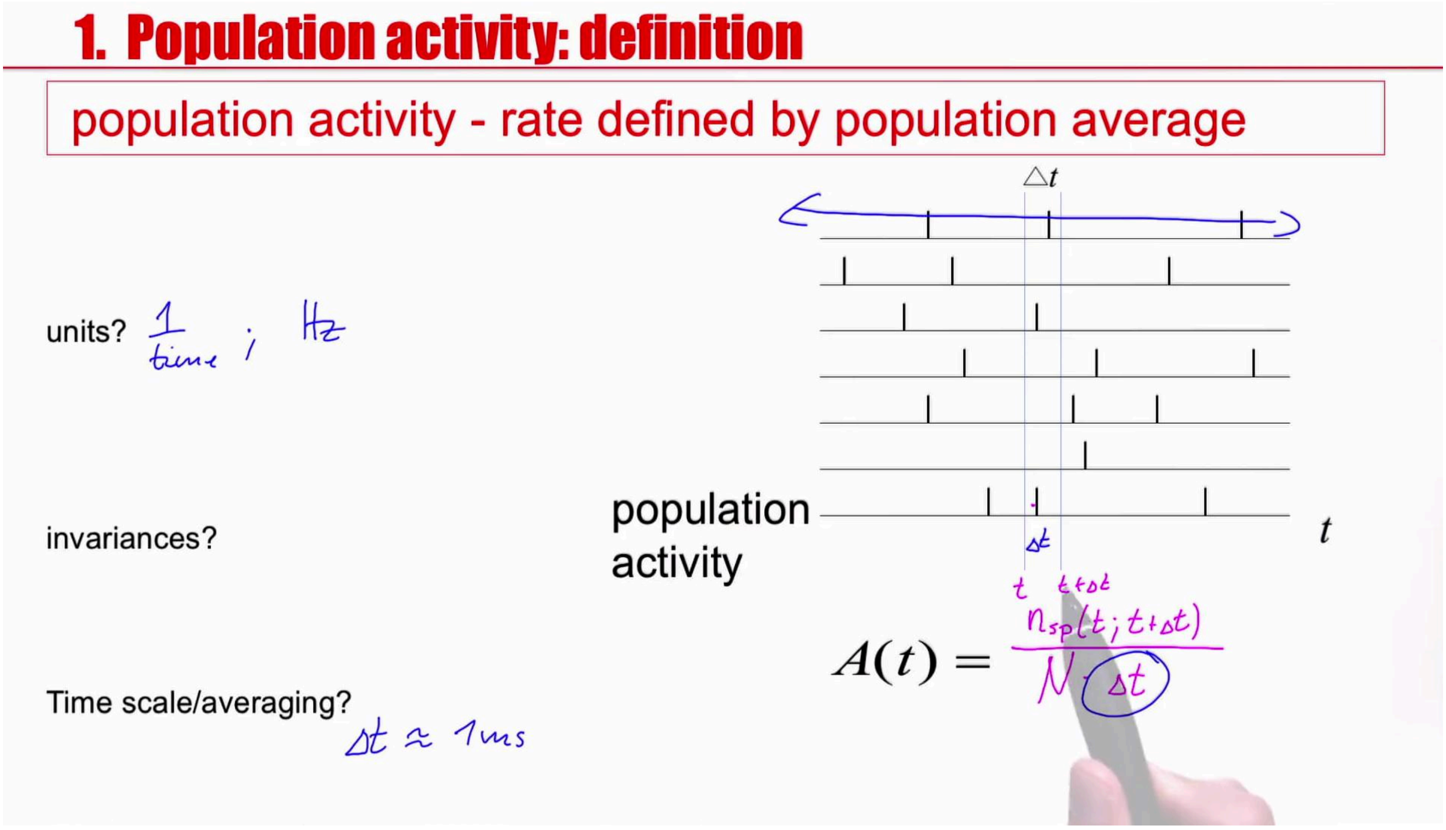


Now, experimentalists nowadays are able to record from many neurons in parallel. So suppose resuming on the legal network and in this network, you would be able to record, many many neurons, then you would see the activity of these neurons you would see these short electrical pulses. So the first neuron would set out spike here, another spike here another spike here, and so forth, as a function of time. The second year and would send out in spikes. The third year and would send out the spikes and so forth. And this is a lot of data. Now one way to analyze this data is you define a very short time window, delta t. And then you just count the number of spikes vertically. Three spikes or one spikes or five spikes. And so as a function of time. You see these different levels of activity.

Notes

Summary

1m 13s

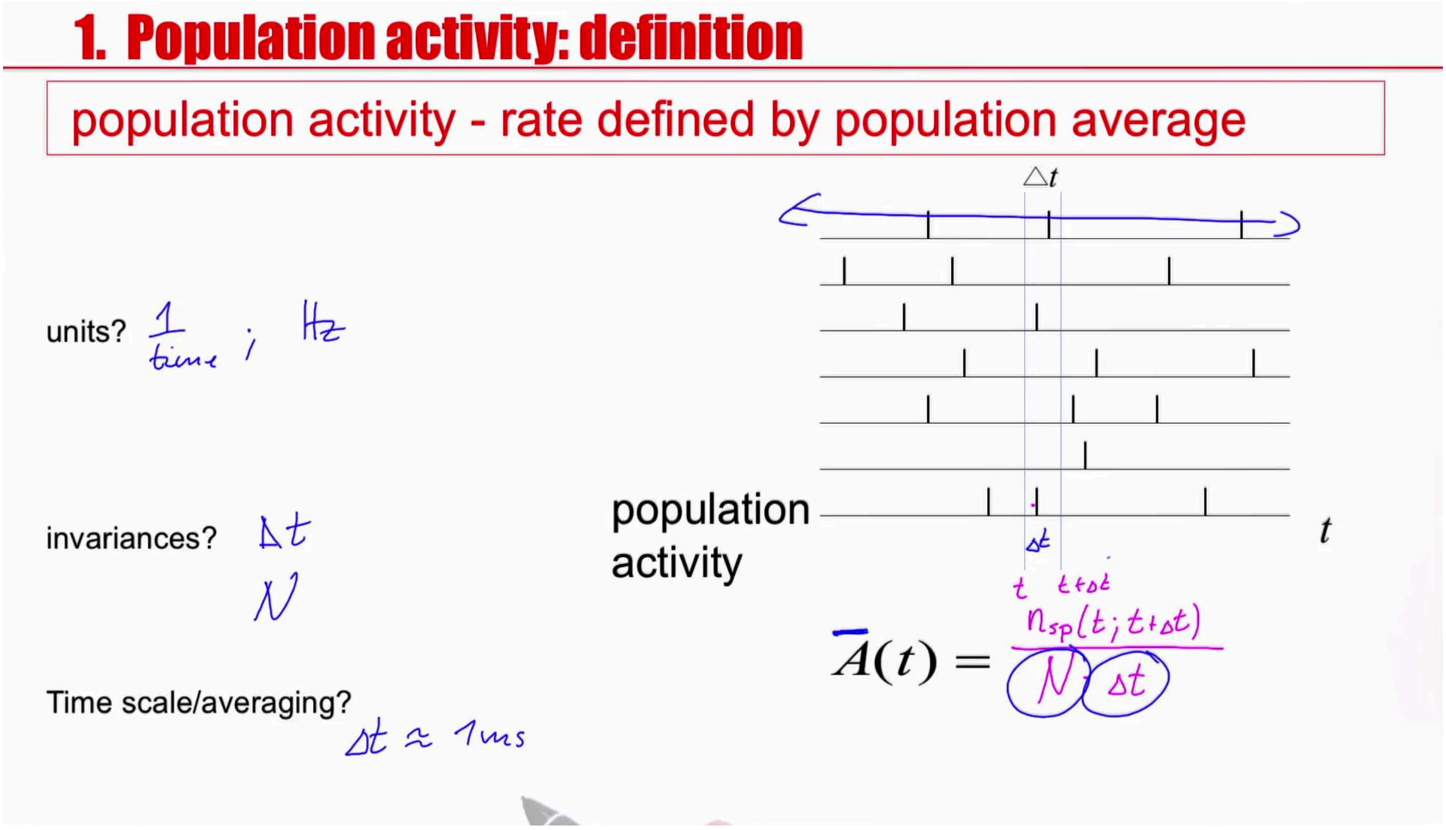


So formally we count the spikes in this short time window delta t. So I count the number of spikes in spikes between time t. In the time t plus delta t spikes of T plus delta t. And then I normalize. I normalize by the total number of neurons, suppose I've in neurons in total. From each i record. And then I also normalize by the delta t. So let's, let's look at this quantity, this quantity has units of one over time. Say units of hertz, has the same units as the fine rate. And in fact, it is a fine rate, or whether, in contrast to a single neuron firing rate, where you will do some tempo averaging over many spikes spike count and divided over long time here its spatial averaging. It's a spike count across different neurons, and then you can choose a very short time scale delta t. So the timescale this short delta t, you can for example take one milliseconds, two milliseconds as a timestamp. And therefore, in each little time step, delta T activity can be different. So you have your record neuronal activity with a high tempo precision. Now, one advantage of divided by delta t is that you get a number that sort of invariant. So you record with a resolution of one millisecond.

Notes

Summary

2m 08s

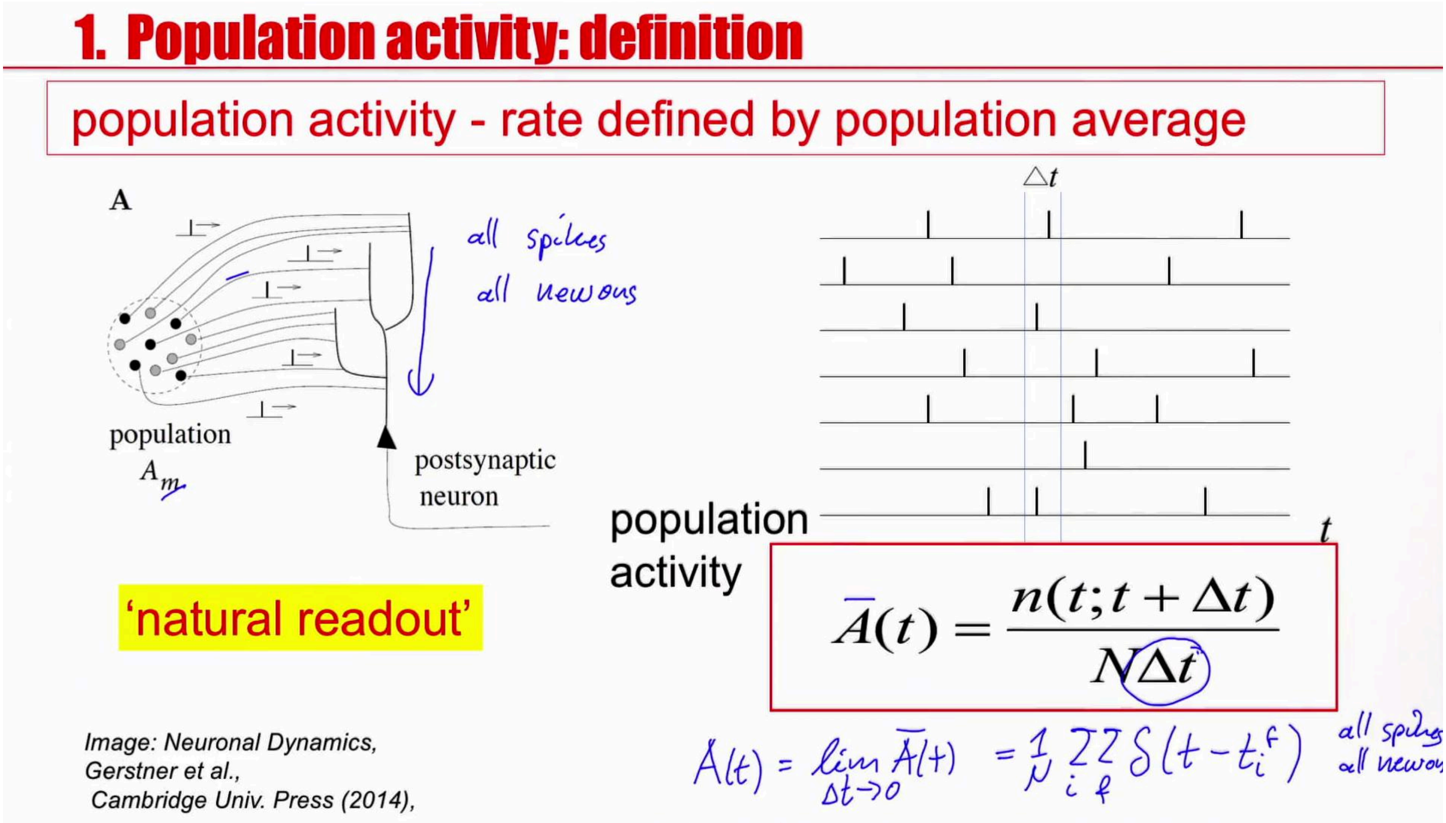


Your colleague records with a resolution of five milliseconds. If both of you divide by delta t, then you get roughly the same numbers. To be in variance with respect to this notion, delta t. Now, suppose you record from a population of, 100 neurons and you get in this time step delta t, you get a fine rate of 25 Hz, your colleague records from 15 neurons but exactly the same difference in the same area. You also get 50 Hz because you divide by the number of neurons that you have requested from. So, this is a useful quantity, it's the population activity. It's a fine rate defined by a population average. And we can also say it's a bar, because we still average over small time step delta t. But as I said delta t is maybe one millisecond or two milliseconds or 3 million things. So it's a really short. It's not averaged over 500 milliseconds or something.

Notes

Summary

3m 47s



So, this quantity, a bar of T averaged over the population of nearing is the population activity or population rate, and I would argue it's a very natural quantity, in the following sense. Think of a new year and that receives input from that population, say population number M population with index M. It receives many spikes. And this neuron, sits here and gets the spike input from all these different neurons. So essentially the input to this neuron is an average of all spikes on neurons. All those neurons that make signals that send signals that make connections to these receiving neuron, the neurons behind the synapse, after the synapse, the post synaptic neuron, and the receiving neuron. So, we still have this little delta t in here, and we can get more independent from Delta T, if we say the activity is the limit of this a bar of T that have defined here in the limit delta t to zero. And then this would just be can make it really small, this will just be the sum of all spikes, and for those who are familiar with his notation, this is the direct delta function or delta distribution by some here, over all new neurons and all spikes, so this is the sum of all spikes and all neurons, and I still have the one over N.

Notes

Summary

4m 49s

1. Population activity: example

population of neurons with similar properties

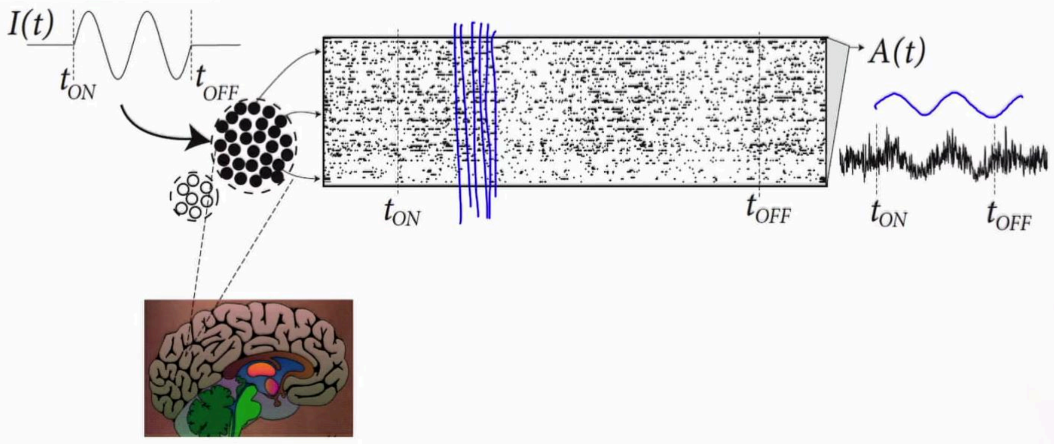


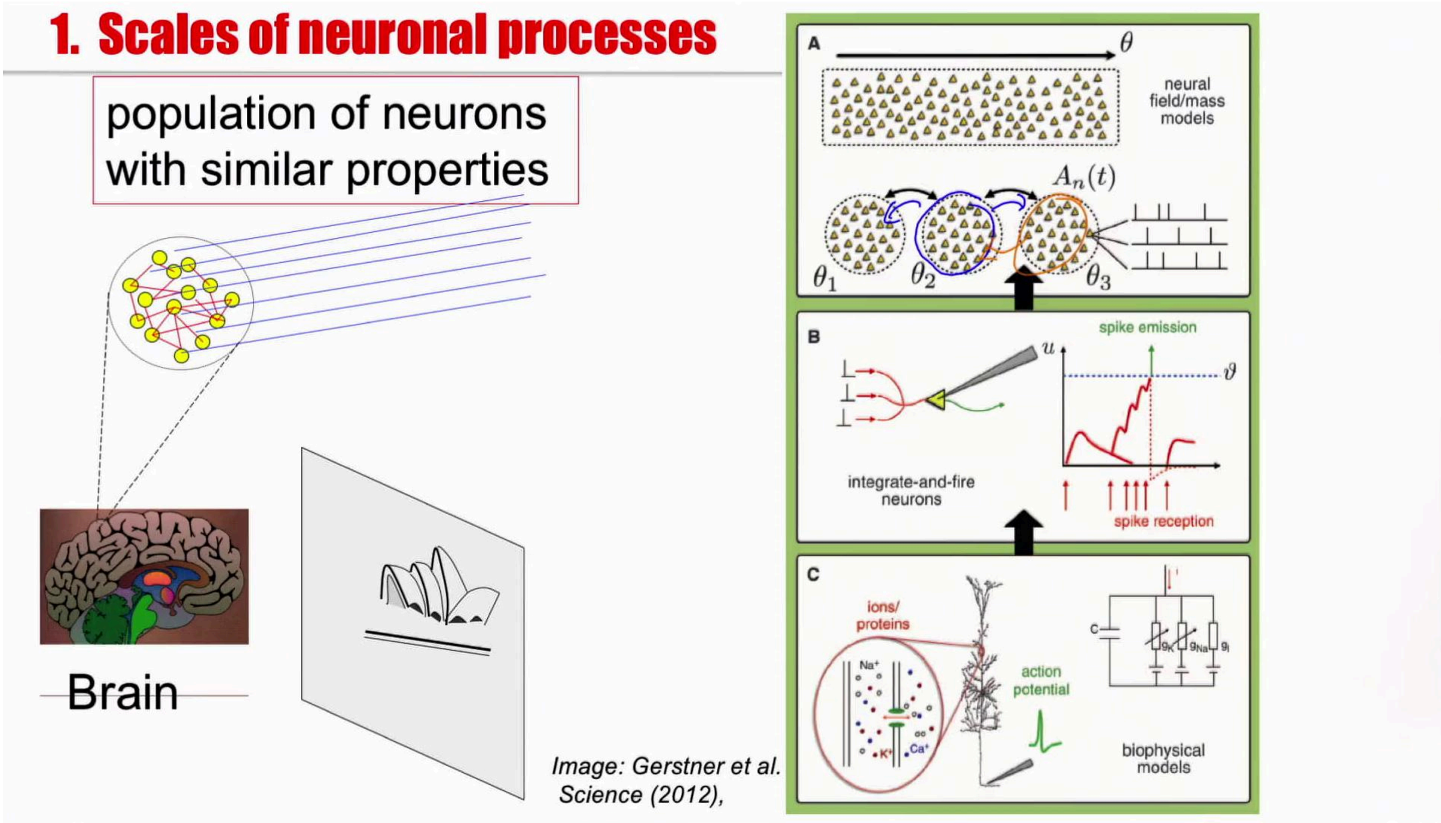
Image: Neuronal Dynamics, Gerstner et al., Cambridge Univ. Press (2014),

So let's just consider it an example here, a population of near and somewhere into brain, suppose there's visual stimulation, you're watching a movie. So the input is going up and down, and as a result of this, these neurons fire, and you see all these spike trains. Now if we do this spatial averaging in some small time steps. Some of the neurons divided by delta t divided by the number of neurons, we get this population activity and this population activity is time dependent. So, we have a temporal of fine temporal resolution of this population activity or population, fighting rate.

Notes

Summary

6m 21s

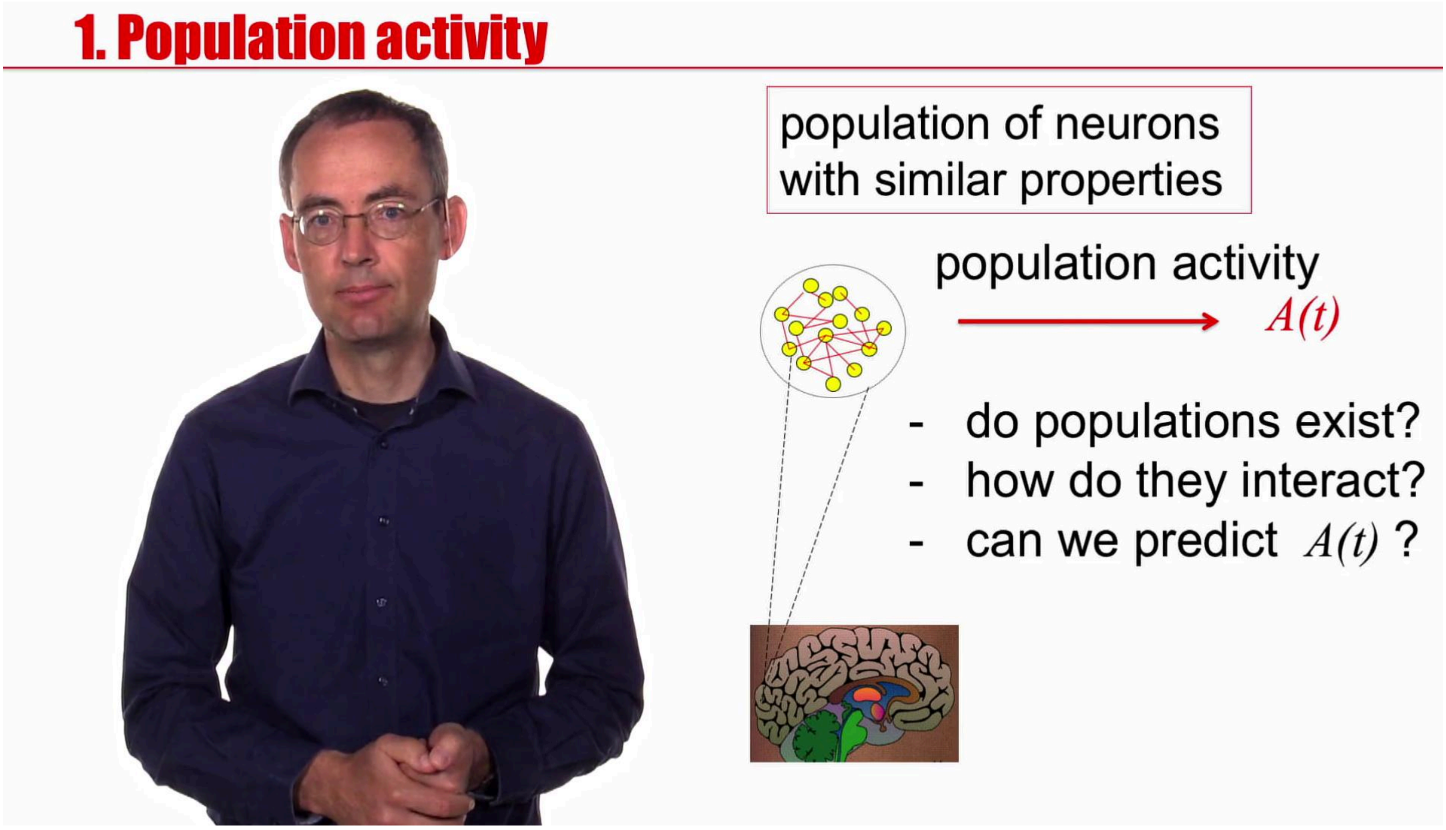


For now, the aim for today's lecture is the following. We could describe the brain on the level of individual neurons and even on the level of individual neurons we could choose, very detailed models that are called biophysical models or compartmental neurons neuron models, or we could use the description on the level of integrated firing neurons if a spike arrives, it causes response, the responses are added, until total membrane potential reaches a threshold, and the spikes emitted, afterwards we restart. It's still a single neuron description, or we could simplify further and preach the scale to a description by populations. And instead of saying, Well, I have 10,000 neurons, these neurons interactive spikes. I now say, I have one population of neurons, and this new population of neurons index with other populations, and it will receive input from other populations. So the inaction is no longer on the level of spikes, but directly on the level of populations.

Notes

Summary

7m 00s



To summarize. In this section we have seen that we can define the population activity in a population of neurons, with similar properties. If you want to do a spatial averaging it's nice to have neurons that are somewhat similar, then it makes sense to do this spatial average. But then the question arises. Are there such populations in the brain? Do such populations exist? And if so, can we predict what the activity would be? And how different populations do interact? These are the questions that people address this week. Stay tuned to find out about the mathematical approaches that will enable us to answer these questions. But before we continue. Let's look at the quiz.

Notes

Summary

8m 10s

Quiz 1, now

The population activity
[ ] Is a firing rate
[ ] Is a fast variable on the time scale of milliseconds
[ ] Is proportional to the number of spikes
counted across a population in a short time window
[ ] Is defined as the number of spikes
counted across a population in a short time window

Notes

Summary

9m 00s

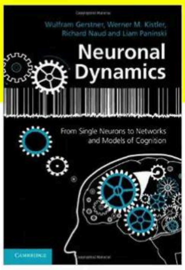
Additional information: Computational Neuroscience

Wulfram Gerstner

EPFL, Lausanne,

Switzerland

Background Reading:
NEURONAL DYNAMICS
- Ch. 1.3.
- Ch. 12.1



Cambridge Univ. Press

Additional links to short MOOC - videos

http://lcn.epfl.ch/~gerstner/NeuronalDynamics-MOOC1.html

- **Dirac delta-function in computational neuroscience**
https://www.youtube.com/watch?v=l3hvrx33lZc

- **Integrate-and-fire model, a first introduction**
https://www.youtube.com/watch?v=gU9UzFeg8f4

Textbook also online:

http://neuronaldynamics.epfl.ch/

Notes

Summary

9m 06s