Sander Keemink

To spike or not to spike: using brain-like signals for control

Neurons communicate with downstream systems with sparse and short-lived electrical pulses, or spikes. Using these incredibly brief spikes, they must affect and control those downstream systems. With the ascent of neuromorphics devices spiking signals are increasingly studied as a control signal, but advances have mostly focussed on using AI techniques to train spiking networks. It remains unclear how spikes could be used in a more principled way. In this talk I take a different approach: how **should** spiking signals be used for control, given both knowledge from computational neuroscience and control theory? We will first look at how to translate the classic optimal control theory of Linear–quadratic–Gaussian control directly to spiking signals --- and we will show that spiking networks can implement these algorithms efficiently and realistically. However, this approach relies on filtering the spiking signal to approximate an analogue control signal --- which ultimately means the neurons have to output a continuous control signal (either through synapses or on hardware by filtering the spikes). We therefore next consider how downstream linear dynamical systems could be controlled solely by brief spiking events, as if a neuron can only give brief 'kicks'. Inspired by linear quadratic control, we require spikes to only happen if it brings a controlled system closer to a target. From this principle, we derive the required connectivity for spiking networks, and show that they can successfully control linear systems. The work gives insight both into how real neurons could control downstream systems like other neurons and muscles, and has applications in neuromorphic hardware design for control tasks where the control output has to be brief and sparse.