1-065. Learning dendritic opinion weighting by cortical neurons

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Successful decision making involves integrating a variety of different opinions, reliable to varying degrees. How should one combine these to maximize the chances for a desired outcome? One option is to weight each opinion according to its estimated reliability.

We suggest that such opinion weighting is naturally performed by cortical neurons. Each dendritic branch forms a local membrane voltage, the analog of an opinion. The reliability of a dendritic branch is encoded in the local membrane conductance. The biophysics of the bidirectional voltage propagation then leads to the formation of a somatic membrane voltage representing a weighted combination of dendritic opinions. A neuron’s output consequently reflects decisions based on the combined dendritic opinions.

In a probabilistic framework we derive somatic membrane potential dynamics which sample from a product model of dendritic probability distributions. For the case of Gaussian noise, the average somatic membrane potential is identical to a Bayes-optimal maximum-a-posteriori estimate (e.g., Knill & Pouget, 2004). We derive a local synaptic plasticity rule which allows the somatic potential to approximate specific target distributions via gradient descent, and additionally assigns appropriate relative reliabilities to different cortical pathways converging on a neuron (cf. Friston, 2018).

We demonstrate successful learning of a prototypical opinion weighting task, namely the integration of multimodal sensory cues to guide behavior. The trained model provides normative interpretations of behavioral and neuronal data from cue integration experiments and makes specific predictions about system behavior and single cell dynamics. The conductance-based nature of synaptic coupling hence may not be an artifact of the biological substrate, but rather enable neurons to perform computations previously thought to be realized at the circuit level. Furthermore, the mathematical and computational tractability of our framework allows its extension to hierarchical and recurrent implementations of neuronal opinion weighting.