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Decision boundaries for maximizing information transmission in neural circuits[1]

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Everything we know about the world around us is represented in the nervous system in sequences of discrete electrical pulses termed spikes. One attractive theoretical idea, going back to 1950s, is that these representations are efficient in the sense of information theory. I will describe an approach for finding the optimal coupling strengths between different neurons that is based on a concept of a decision boundary [1]. In this framework, neural circuit responses are described by specifiying for each neuron the decision boundary that separates multi-dimensional signals that elicit a spike in that neuron from those signals that do not elicit a spike. The shape and position of individual neurons' boundaries determine the amount of mutual information that the neural circuit can transmit about the incoming signals. Correspondingly, the optimal configuration of the decision boundaries depends on the probability distribution of incoming signals. Signals typical of our natural sensory environment are known to be strongly correlated and to possess large-amplitude deviations that are often better described by an exponential rather than a Gaussian distribution. Considering exponentially distributed signals, we find that optimal decision boundaries of neurons are curved, and that they exhibit sharp discontinuities when decision boundaries of different neurons intersect. This, in turn, corresponds to non-zero coupling constants when these neural circuits are described using the pairwise maximum entropy models.

[1] T. Sharpee and W. Bialek, PLoS One, e646 (2007).

[1]NIH/NIMH, Alfred P. Sloan Fellowship, Searle Foundation