Neural coding

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Receptive fields and tuning curves

Tuning curve: $r = f(s)$

Gaussian tuning curve of a cortical (V1) neuron
Receptive fields and tuning curves

Tuning curve: \( r = f(s) \)

Hand reaching direction

Cosine tuning curve of a motor cortical neuron
Receptive fields and tuning curves

Retinal disparity for a “near” object

Sigmoid/logistic tuning curve of a “stereo” V1 neuron
More generally, we are interested in determining the relationship:

\[ P(\text{response} \mid \text{stimulus}) \quad \text{encoding} \]

\[ P(\text{stimulus} \mid \text{response}) \quad \text{decoding} \]

Due to noise or uncontrolled factors, this is a stochastic description.

Problem of *dimensionality*, both in response and in stimulus
Basic coding model: relationship with sensory input

Linear filter: $r(t) = \int f(t-t) s(t) \, dt$
Next most basic coding model

Linear filter & nonlinearity: $r(t) = g(\int f(t-t) s(t) \, dt)$
The spike-triggered average

Example: a neuron in the ELL of a fish

stimulus = fluctuating potential
  (generates electric field)
The spike-triggered average

This can be done with other dimensions of stimulus as well

Spatio-temporal receptive field
Determining the nonlinear input/output function

The input/output function is:

\[ P(\text{spike}|\text{stimulus}) \]

which can be derived from data using Bayes’ rule:

\[ P(\text{spike}|s_1) = \frac{P(s_1|\text{spike})P(\text{spike})}{P(s_1)} \]

It is often useful to look simply at the conditional distribution

\[ P(s_1) \]

\[ P(s_1|\text{spike}) \]
Dimensionality reduction

More generally, one can conceive of the action of the neuron or neural system as selecting a low dimensional subset of its inputs.

\[ \text{P(response | stimulus)} \rightarrow \text{P(response | s_1, s_2, .., s_n)} \]

Start with a very high dimensional description (eg. an image or a time-varying waveform) and pick out a small set of relevant dimensions.

\[ S(t) = (S_1, S_2, S_3, .., S_n) \]
Models with spike history

GLM: $r(t) = g(f_1^*s + f_2^*r + ...)$