Decoding

Bayes Theorem and Basic Probability

$P(A)$ =Probability of Event A
$P(A, B)$ =Probability of Event A **and** Event B.
$P(B|A)$ =Probability of Event B **given** Event A occurred.
Hence $P(A, B) = P(A)P(B|A)$ also $P(A, B) = P(B)P(A|B)$ therefore

$$P(A|B) = \frac{P(A)P(B|A)}{P(B)} \tag{1}$$

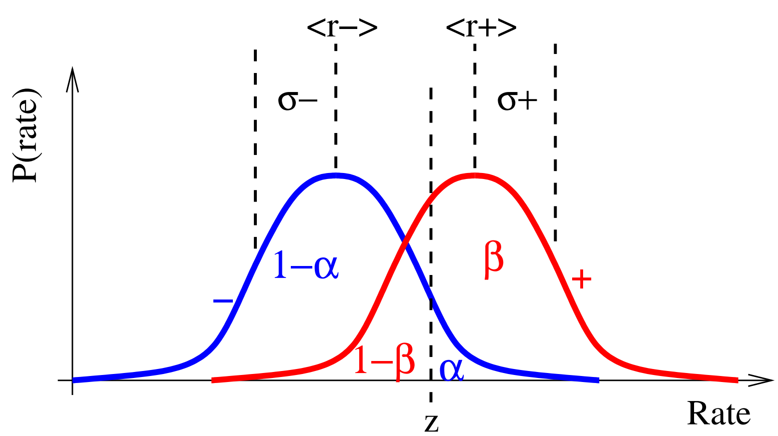
This is Bayes' Theorem.

For decoding, A = specific stimulus, B = spike train, so $P(A|B)$ is the probability of a specific stimulus in outside world (what we want to know) given a specific spike train (the information within our heads). Given a spike train, we want to know the most likely stimulus that produced it — the maximum $P(A|B)$.

In this case, $P(A)$ is the **Prior** probability. Everything we perceive in the world depends on prior assumptions about the world! [If we assume something impossible, so $P(A) = 0$ then whatever our neurons say — for any B — we have $P(A|B) = 0$.]

Discrimination and Receiver-Operating Characteristic, ROC

Discriminability, $d' = \frac{<r(+)>-<r(-)>}{\overline{\sigma}}$ where $\overline{\sigma} = \sqrt{\frac{\sigma_+^2+\sigma_-^2}{2}}$.



z = threshold rate. β is area under +curve above threshold (probability of correct response, power). α is area under −curve above threshold (probability of false positive).

For large z: α, $\beta \mapsto 0$.
For low z: α, $\beta \mapsto 1$.
ROC curve: plot $\beta(z)$ versus $\alpha(z)$.
Diagonal $\alpha = \beta$: no information from neuron (area = 1/2).
Full information if $\beta \mapsto 1$ when $\alpha \approx 0$ (area = 1).

Anti-neuron An anti-neuron is a neuron that is tuned to the opposite input to the neuron being measured. If we measure a neuron in MT that fires the most to dots moving to the right (and least to the left) its anti-neuron fires most to dots moving to the left (and least to the right). When measuring from only one neuron, two separate experiments are needed (with opposite stimuli) to get the information that is available within the brain in one experiment using two neurons (the neuron and anti-neuron pair).

Prove: Area under ROC curve is probability of correct choice based on rates from a neuron/anti-neuron pair.

Note: this is based on a strong, almost certainly unrealistic assumption that the firing rate of the "anti-neuron" (**-**neuron) is **independent** of the firing rate of the **+**neuron.

How do correlations affect the discrimination?

Likelihood Ratio

$$l(r) = \frac{p(r|+)}{p(r|-)} \tag{2}$$

Given by the gradient of the ROC curve.

General strategy, if $l(r) >$ some threshold, pick $+$.

Optimal threshold depends on loss functions, L_+, L_- if goal of choice is to minimize loss:

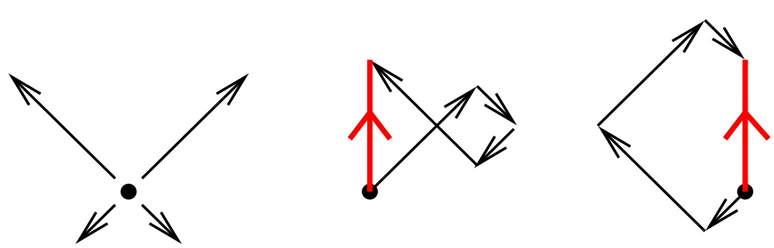
$$l(r) \geq \frac{L_+}{L_-}\frac{P(-)}{P(+)} \tag{3}$$

Population Vector

Normalize by maximum firing rate of neuron – other possibilities.

Create a vector for each neuron directed in its preferred direction, with a length that depends on its firing rate.

4 neurons: population vector.



Note: (1) A neuron is most sensitive to distinguishing stimuli at the steepest part of its tuning curve, not stimuli that cause maximal firing rates.

(2) This is one estimation that is intuitive, but statistically sub-optimal compared to other methods such as Maximum Likelihood.