Neural coding

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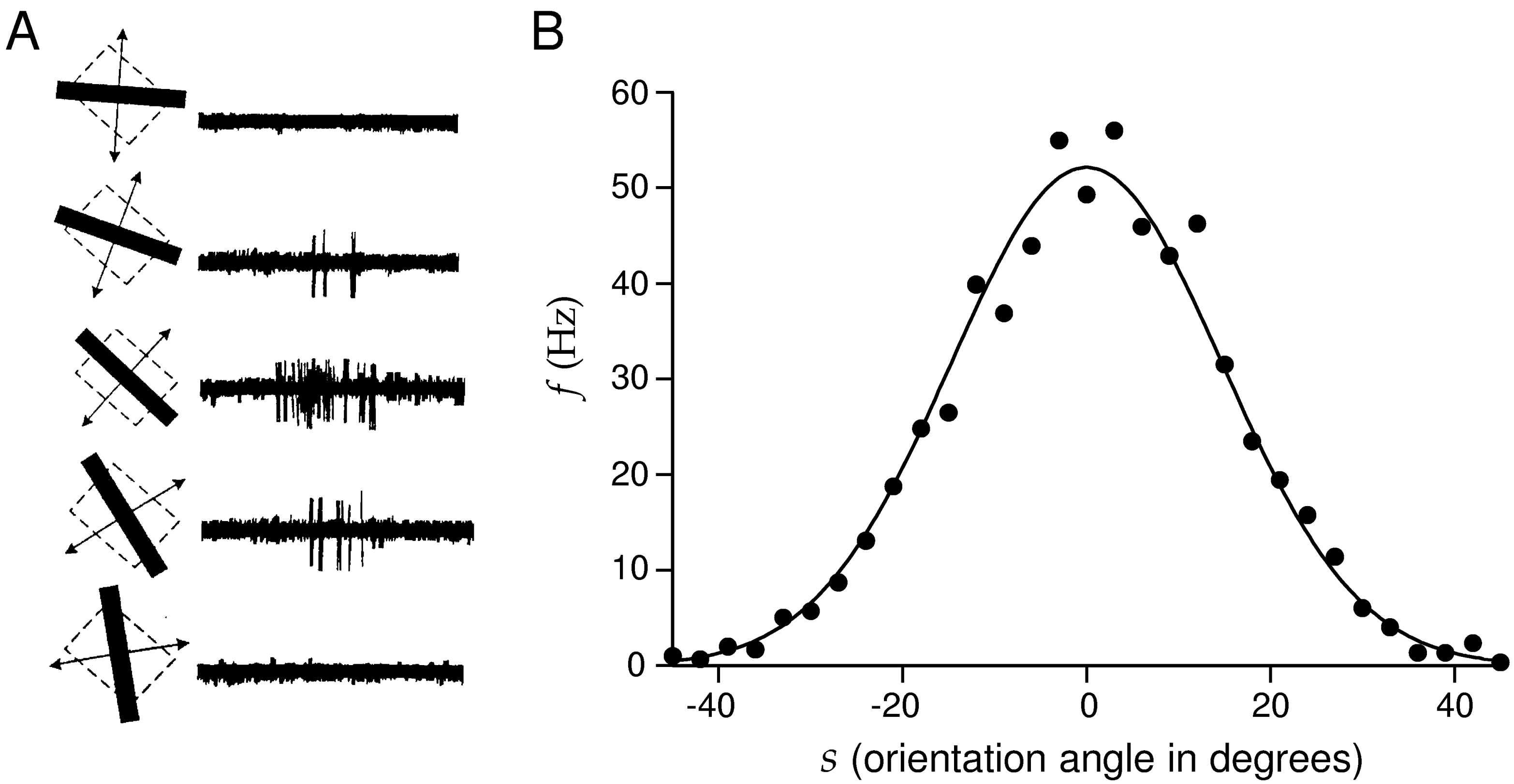
MCN 1997

Receptive fields and tuning curves

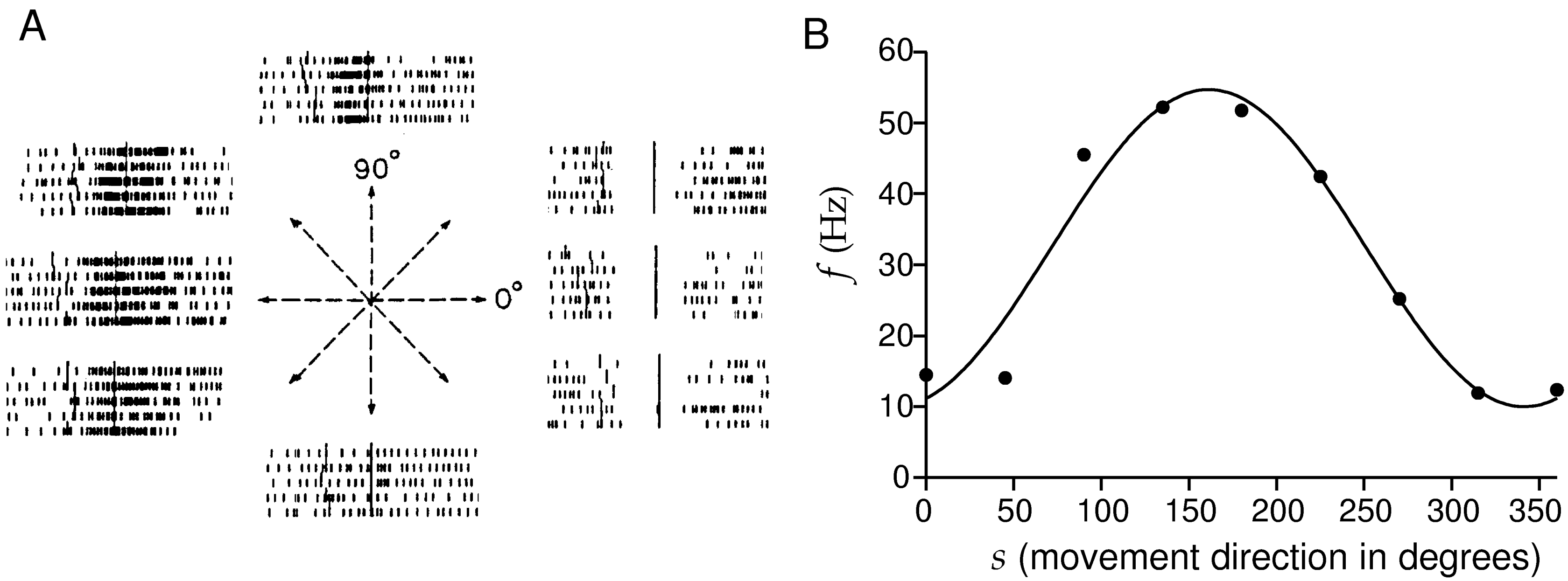
Tuning curve: r = f(s)



Gaussian tuning curve of a cortical (V1) neuron

Receptive fields and tuning curves

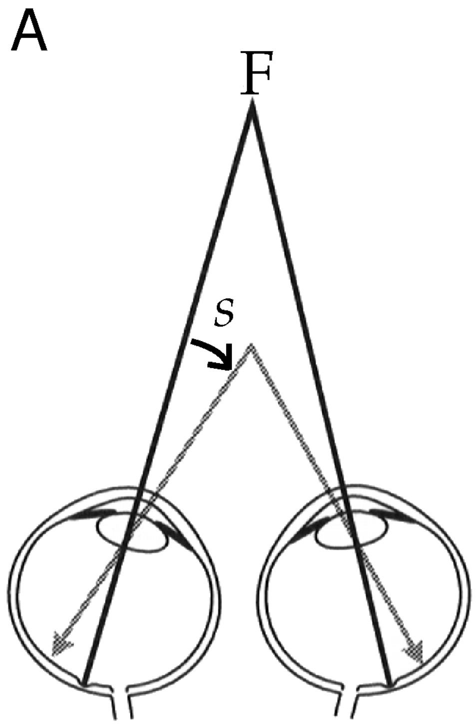
Tuning curve: r = f(s)



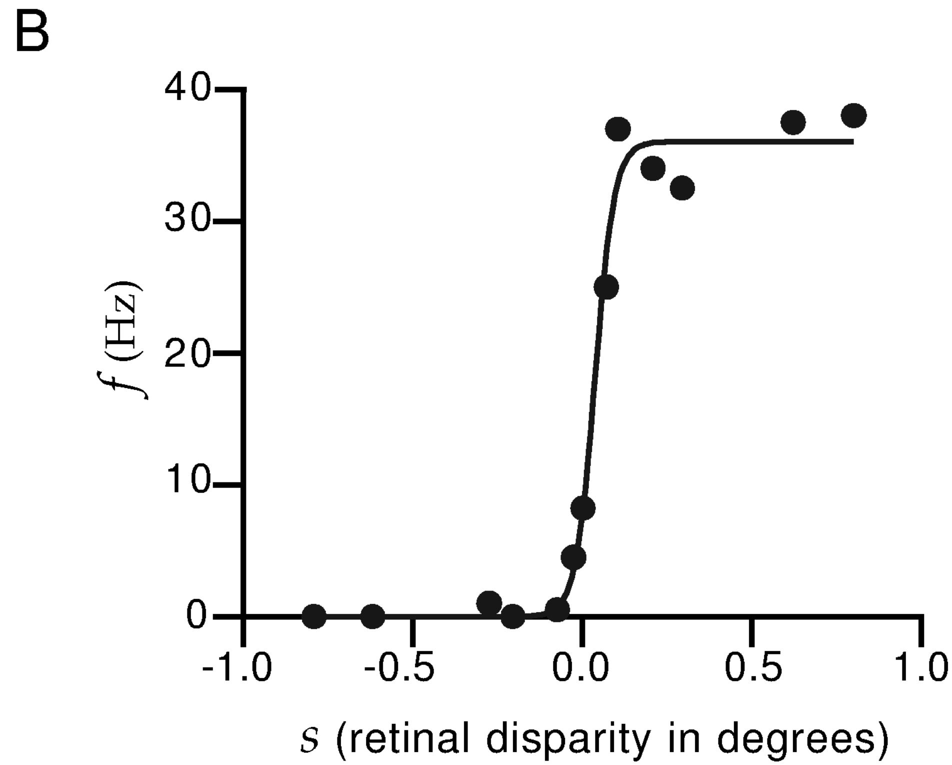
Hand reaching direction

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:

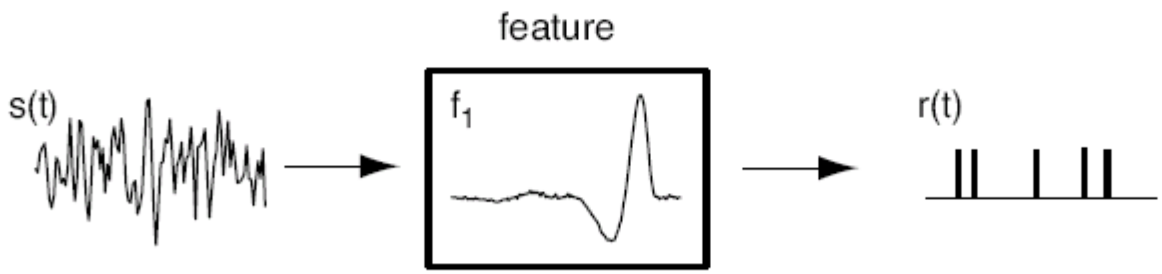
$\boxed{\text{P(response | stimulus)}}$ *encoding*

$\boxed{\text{P(stimulus | response)}}$ *decoding*

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

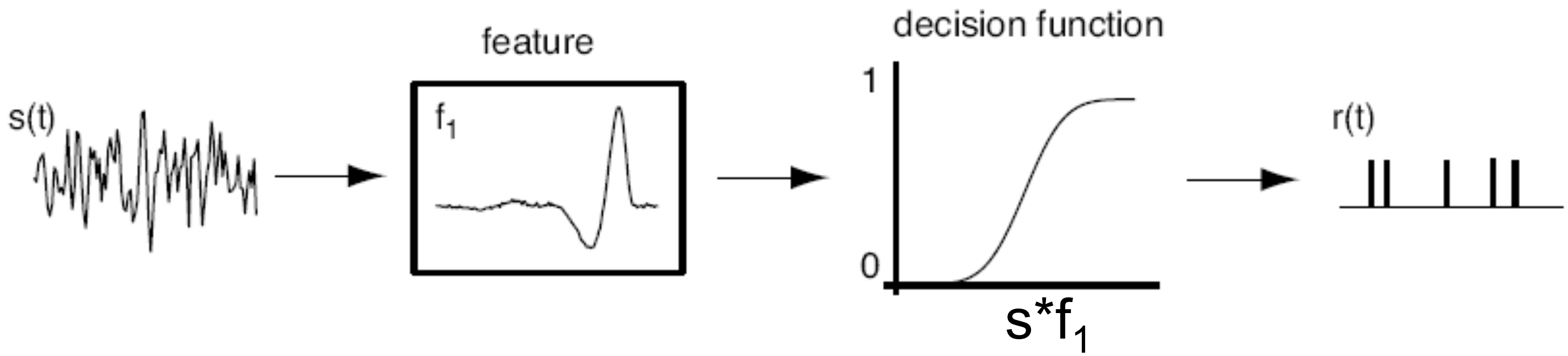
Problem of *dimensionality*, both in response and in stimulus

Basic coding model: relationship with sensory input



Linear filter: $r(t) = \int f(t-t)\, s(t)\, dt$

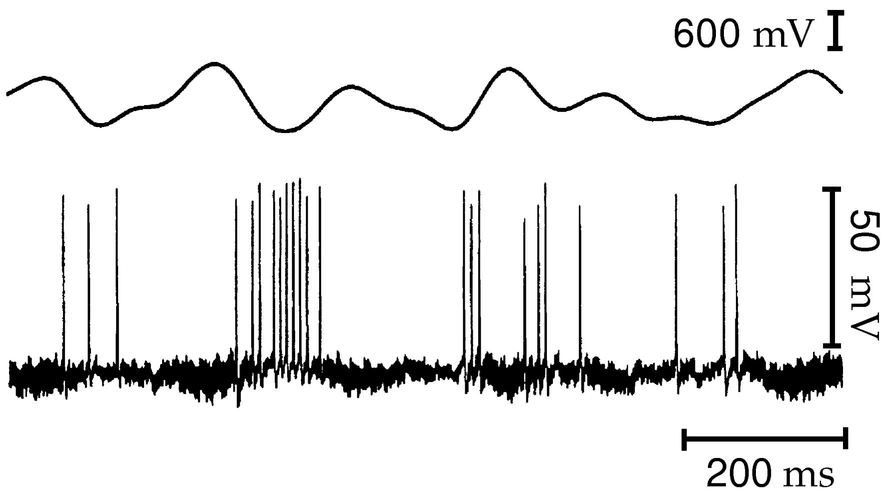
Next most basic coding model



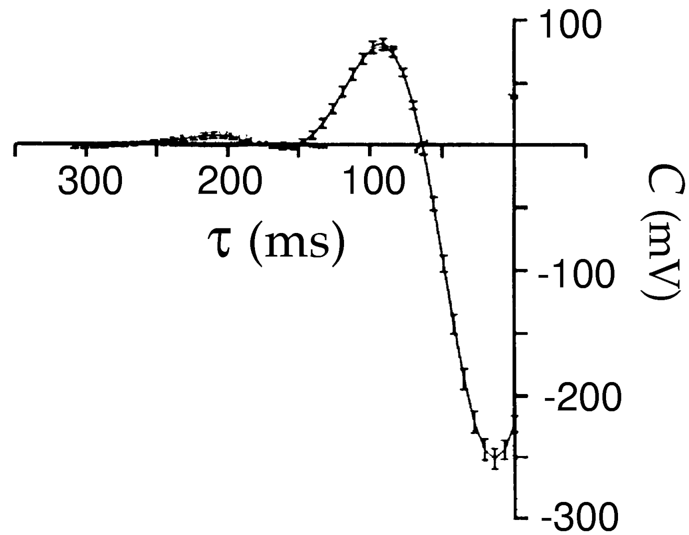
Linear filter & nonlinearity: $r(t) = g(\int f(t-t)\ s(t)\ dt)$

Example: a neuron in the ELL of a fish

stimulus = fluctuating potential
(generates electric field)



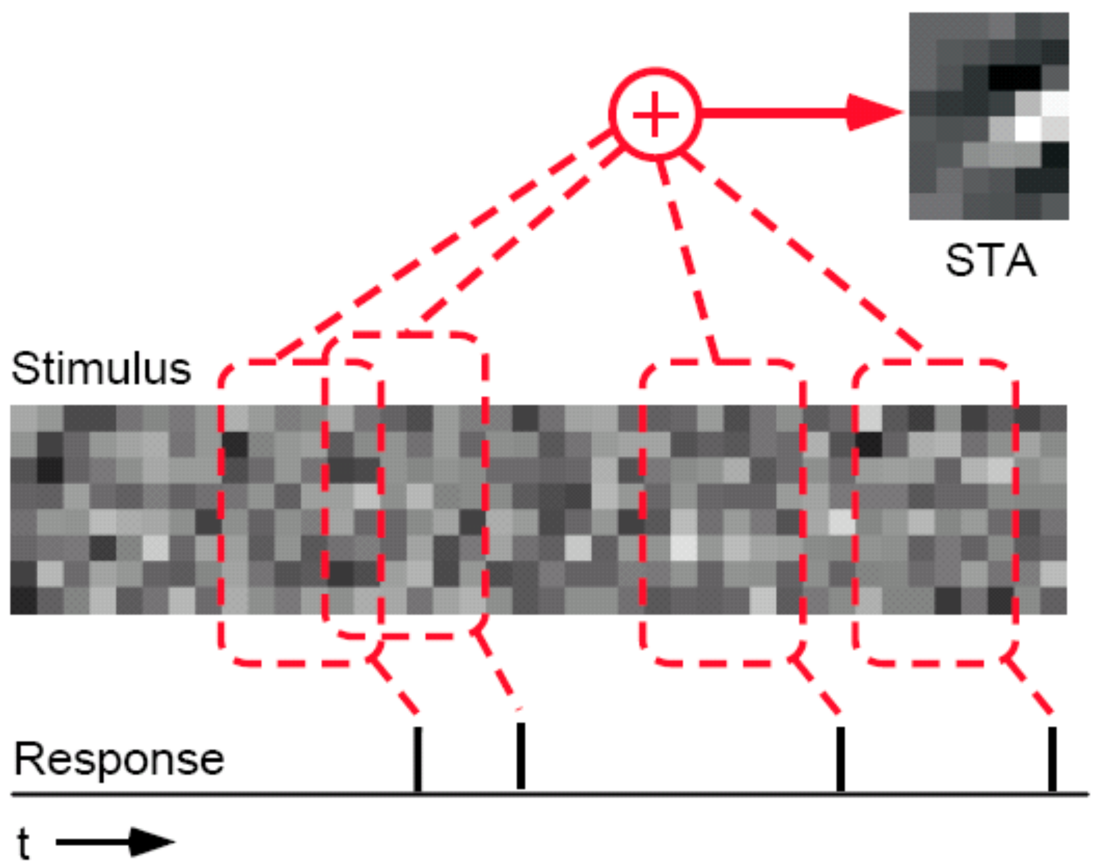
Spike-triggered Average



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:

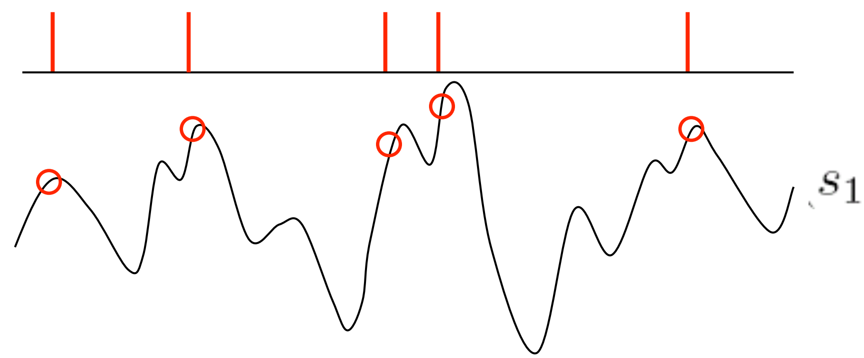
$$P(\text{spike}|\text{stimulus})$$

which can be derived from data using Bayes' rule:

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

$P(s_1)$

$P(s_1|\text{spike})$



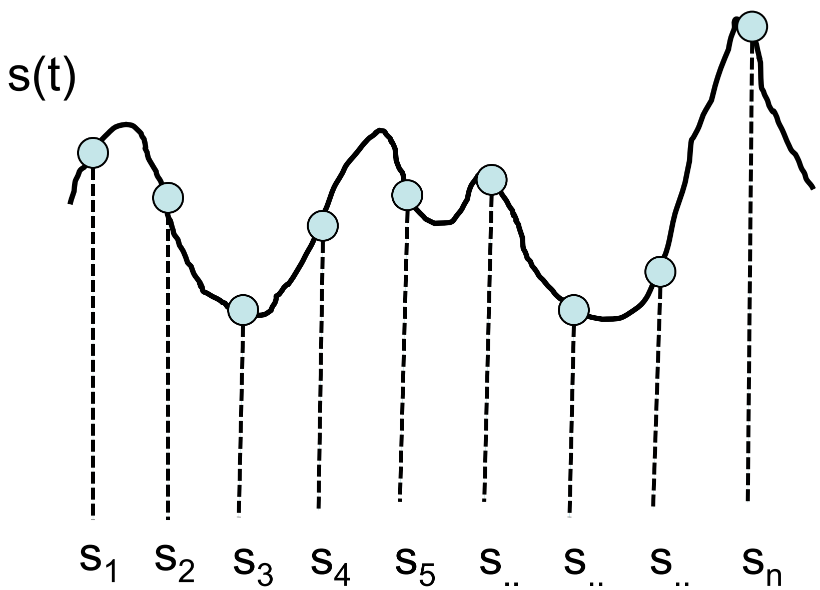
It is often useful to look simply at the conditional distribution

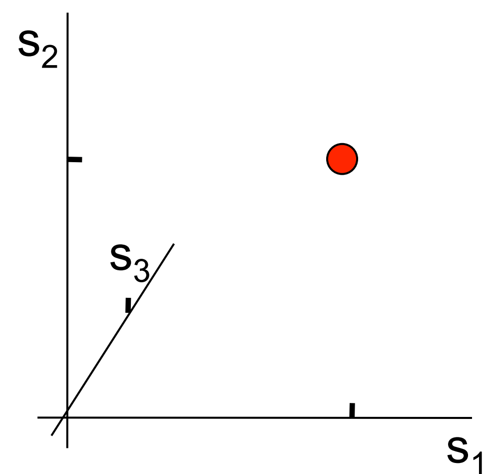
Dimensionality reduction

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

$$P(\text{response} \mid \text{stimulus}) \rightarrow P(\text{response} \mid s_1, s_2, .., s_n)$$

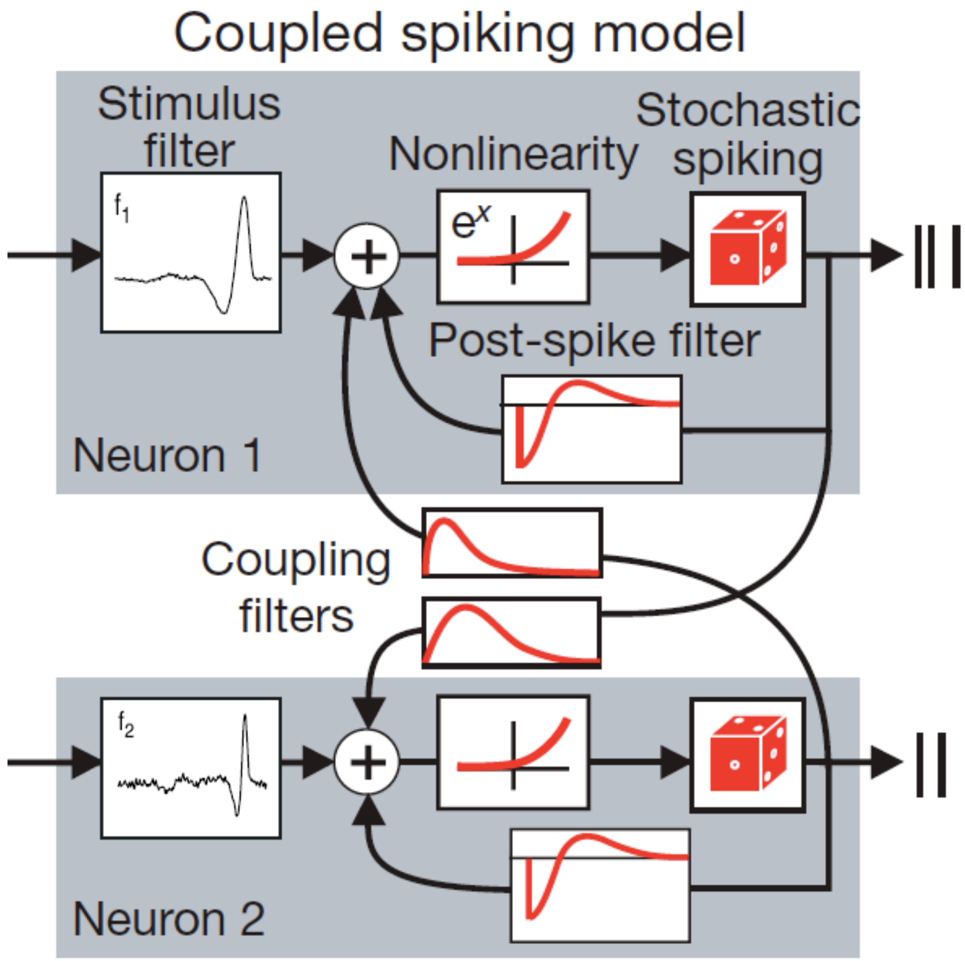
Start with a very high dimensional description (eg. an image or a time-varying waveform) and pick out a small set of relevant dimensions.





$S(t) = (S_1,S_2,S_3,\ldots,S_n)$

Models with spike history



GLM: $r(t) = g(f_1 * s + f_2 * r + \ldots)$

Pillow et al., *Nature* 2008; Truccolo, .., Brown, *J. Neurophysiol*. 2005