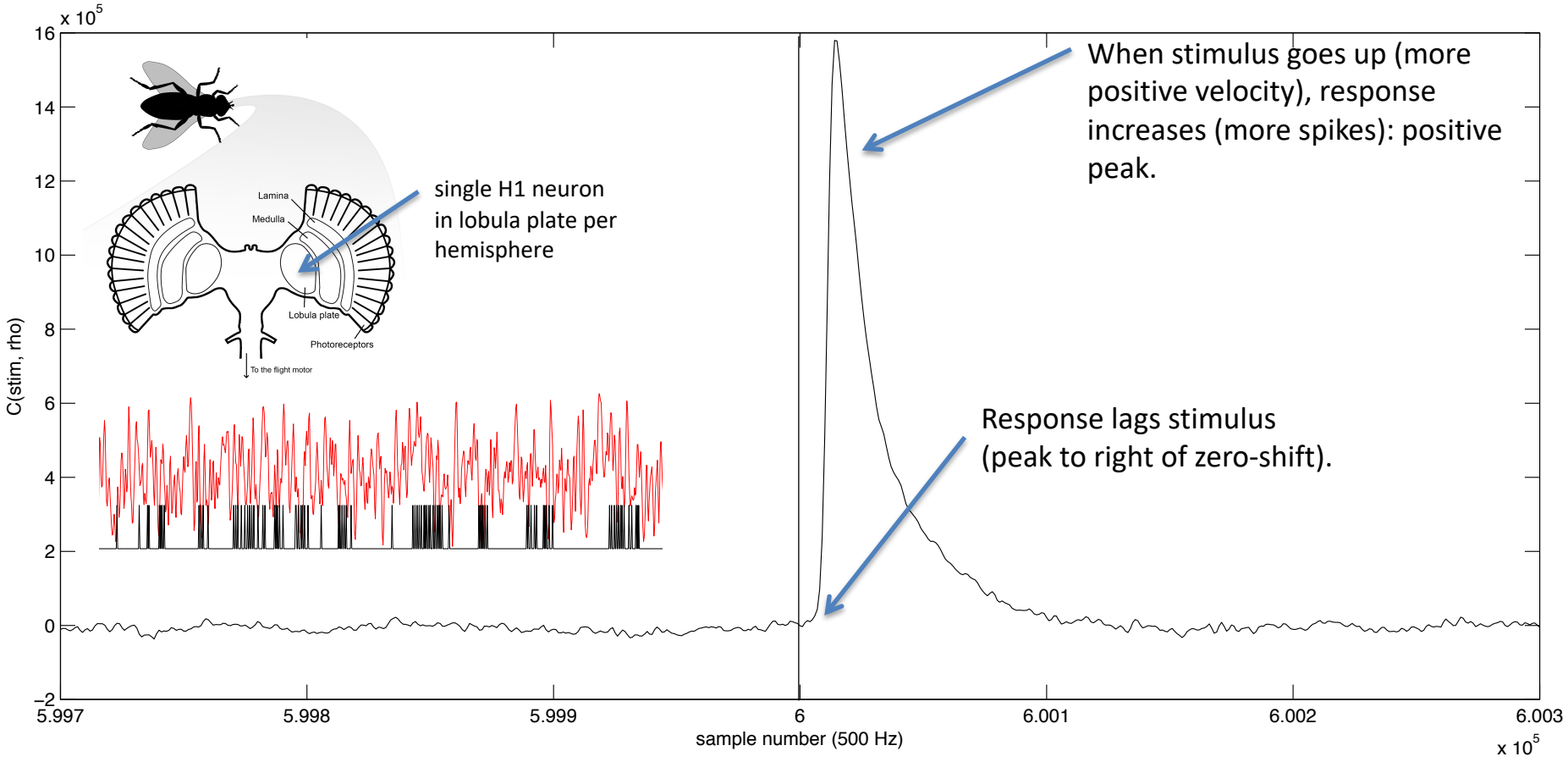
STA and the encoding and decoding problems

NEU 466M

Spring 2018

Last time: stimulus, spike cross-correlation



Cross-correlation uncovers relationships between time-series.
What specifically does it mean about stimulus → spike response?

Back to original goal: Modeling

WHAT DOES IT MEAN TO BUILD A MODEL OF OBSERVATIONS OF A STIMULUS AND RESPONSE?

Modeling spike train data

Model: Simple, predictive description.

But what is it we want to describe/predict?

Option 1) Given stimulus, predict spikes?

Option 2) Given spikes, “predict” stimulus?

Modeling spike train data

Model: Simple, predictive description.

But what is it we want to describe/predict?

Option 1): Given stimulus, predict spikes?

Encoding model

Option 2): Given spikes, “predict” stimulus?

Modeling spike train data

Model: Simple, predictive description.

But what is it we want to describe/predict?

Option 1): Given stimulus, predict spikes?

Encoding model

Option 2): Given spikes, “predict” stimulus?

Decoding model

Modeling spike train data

Model: Simple, predictive description.

But what is it we want to describe/predict?

Option 1): Given stimulus, predict spikes?

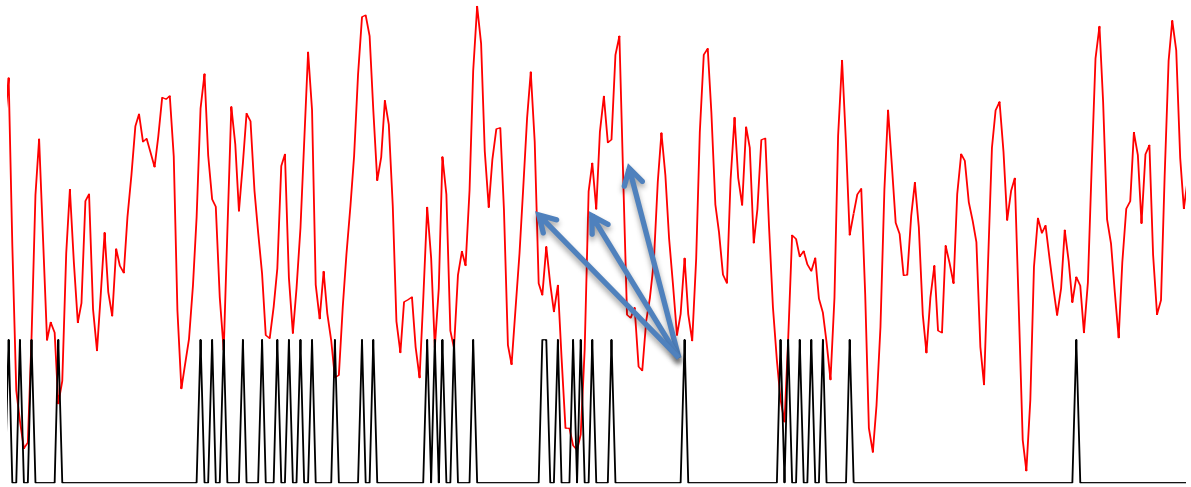
Encoding model

Option 2): Given spikes, “predict” stimulus?

Decoding model

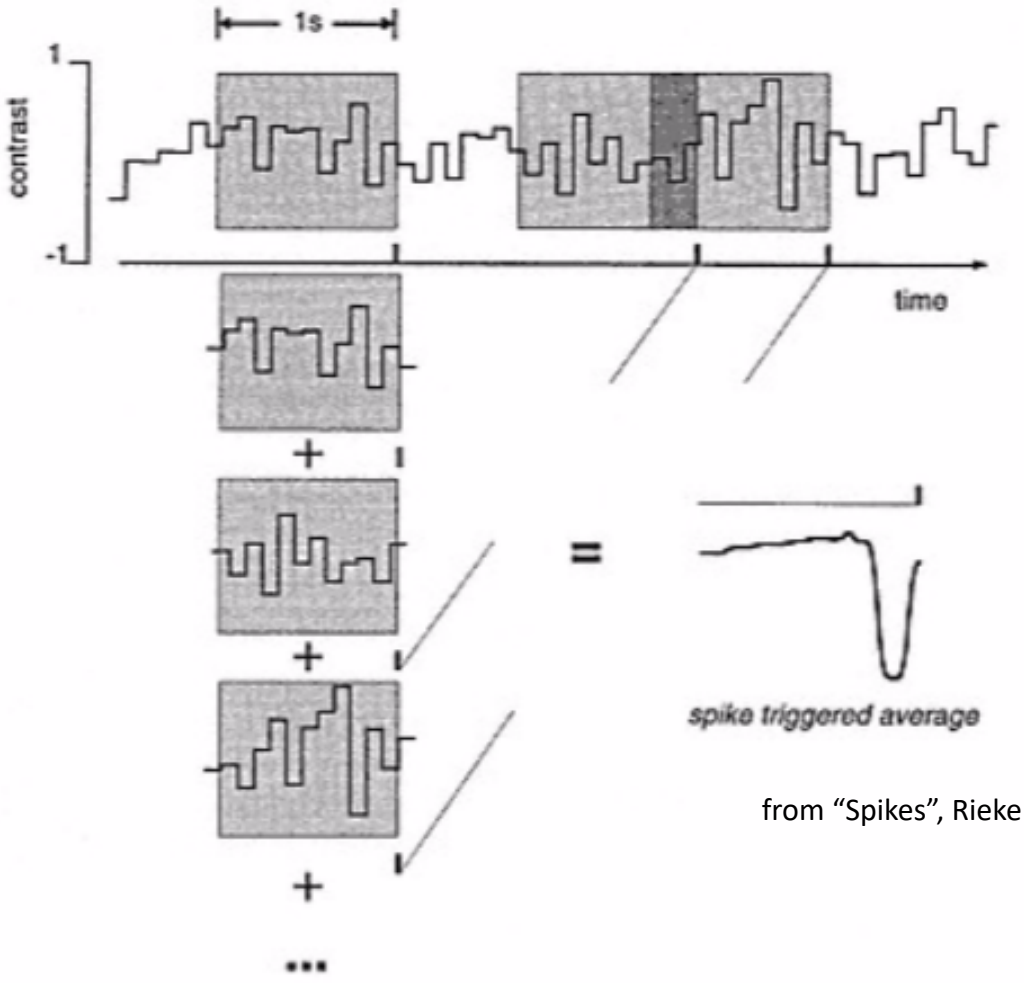
Both are good and closely related modeling goals!

Decoding problem



Given a spike, what was the stimulus?

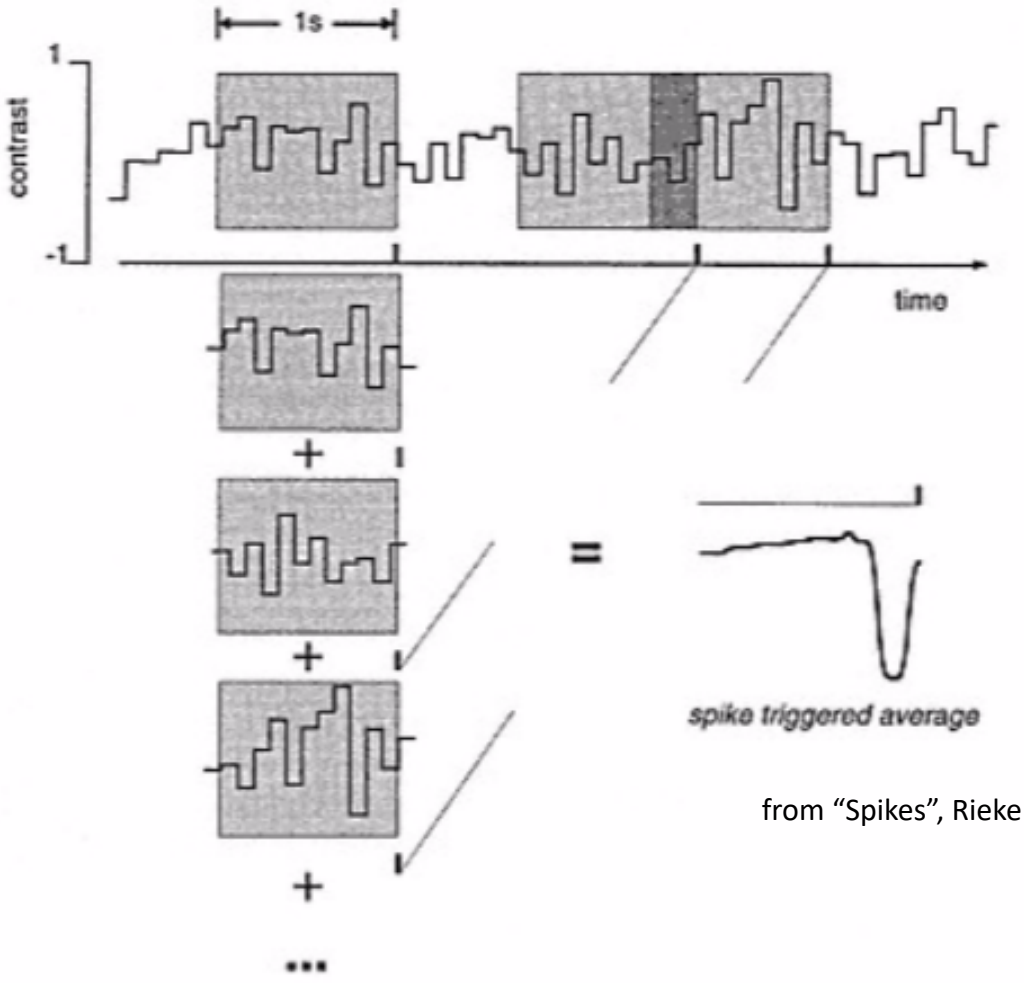
The spike-triggered average



from “Spikes”, Rieke et al.

Given a spike, what was the mean stimulus that led up to it?

The spike-triggered average



from “Spikes”, Rieke et al.

STA: (average) stimulus “feature” to which cell responds

The spike-triggered average

stimulus $s(t)$

N spikes at times t_i $(i = 1 \cdots N)$

$$\mathrm{STA}(\tau) = \frac{1}{N} \sum_{i=1}^{N} s(t_i - \tau)$$

The spike-triggered average as a correlation

$$\begin{aligned}\mathrm{STA}(\tau) &= \frac{1}{N}\sum_{i=1}^{N} s(t_i - \tau) \\ &= \frac{1}{N}\sum_{t} \rho(t)s(t-\tau) \\ &= \frac{1}{N} C_{\rho s}(-\tau)\end{aligned}$$

ρ is the spike vector of $0's, 1's$

STA = Correlation between spike-train, stimulus at negative (earlier) times

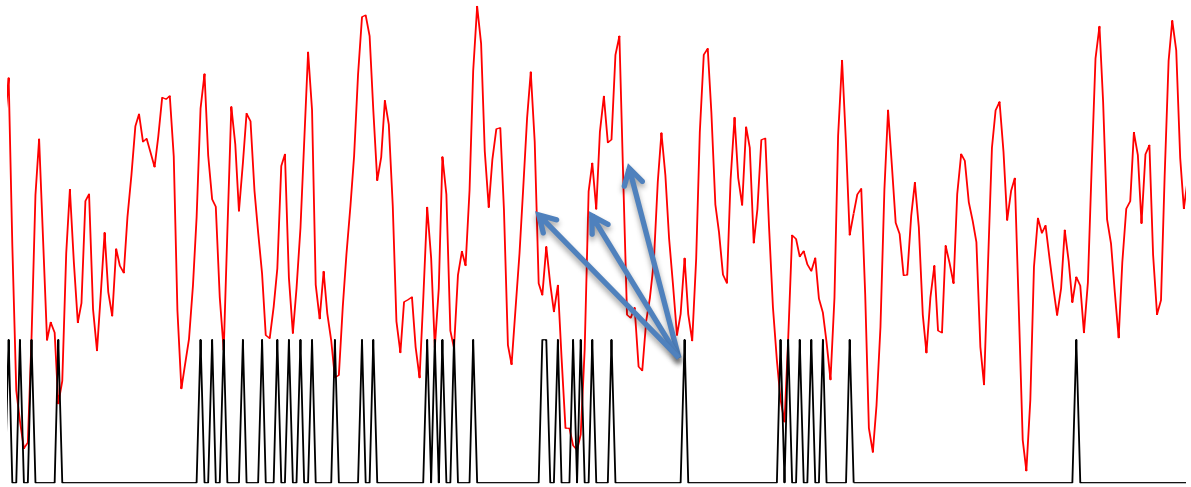
"Reverse correlation"

STA and reverse correlation

- STA assumes that the response is a binary spike-train.

- Reverse correlation: the response can be any time-varying signal. Also called “white noise” analysis (we will see why later).

STA and the decoding problem



Decoding problem: Infer stimulus given spike train. “Mindreading”: read spike output and infer what the brain saw.

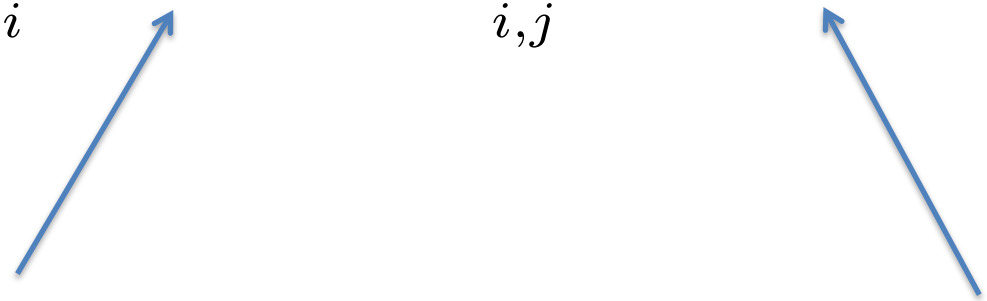
STA: Given that cell fired spike, STA returns average of preceding stimulus.

Decoding problem

Volterra series expansion:

$$\begin{array}{l}\text{stimulus } s(t)\\ N \text{ spikes at times } t_i \ (i = 1 \cdots N)\end{array}$$

$$s_{est}(t) = \sum_i F_1(t - t_i) + \sum_{i,j} F_2(t - t_i, t - t_j) + \cdots$$



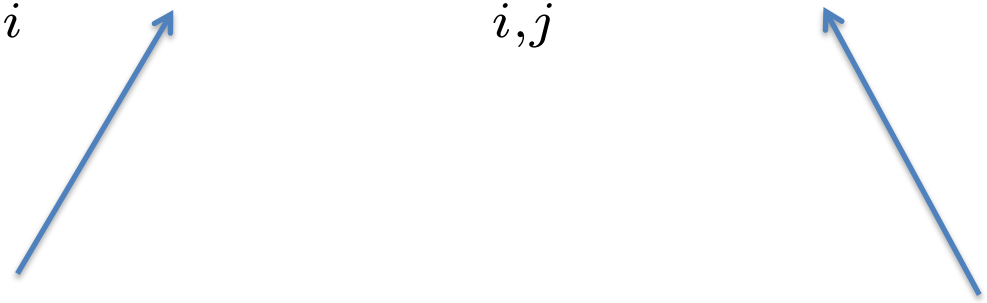
each spike an independent event, and contributes independently to stimulus reconstruction

spike pairs in specific configuration carry information about stimulus, beyond that contained in their individual occurrences. spike pair a separate event contributing to reconstruction.

Decoding problem

Volterra series expansion:

$$s_{est}(t) = \sum_i F_1(t - t_i) + \sum_{i,j} F_2(t - t_i, t - t_j) + \cdots$$



each spike an independent event given stimulus, and contributes independently to stimulus reconstruction

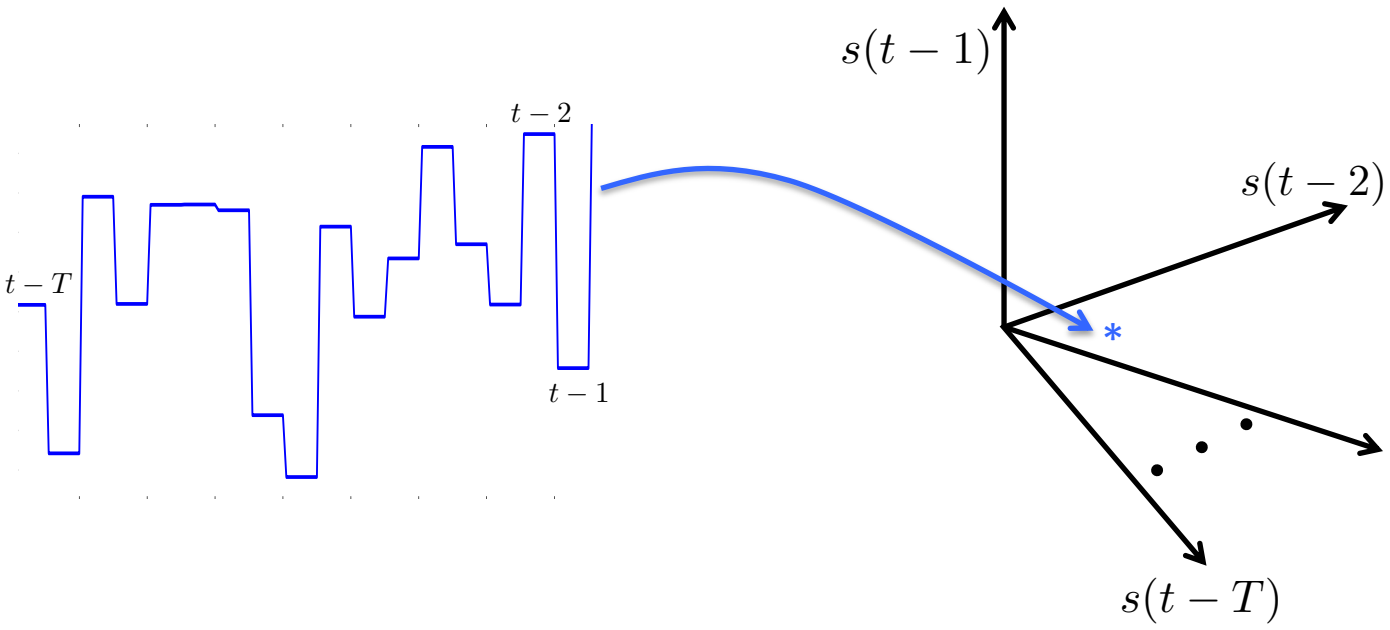
STA

spike pairs in specific configuration carry information about stimulus, beyond that contained in their individual occurrences. spike pair an independent event contributing to reconstruction.

Geometric view

length-*T* stimulus vector preceding time point *t*:

$$\{s(t-T)\cdots s(t-2)s(t-1)\}$$

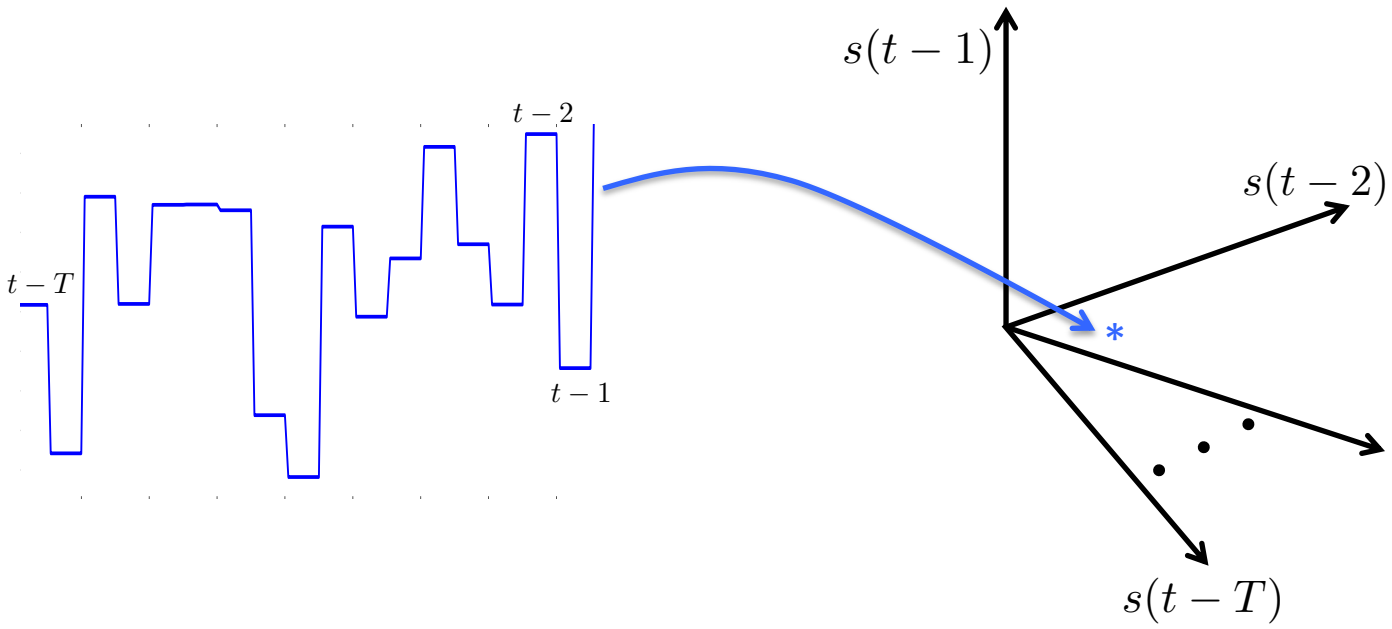


stimulus space

Geometric view

length-*T* stimulus vector preceding time point *t*:

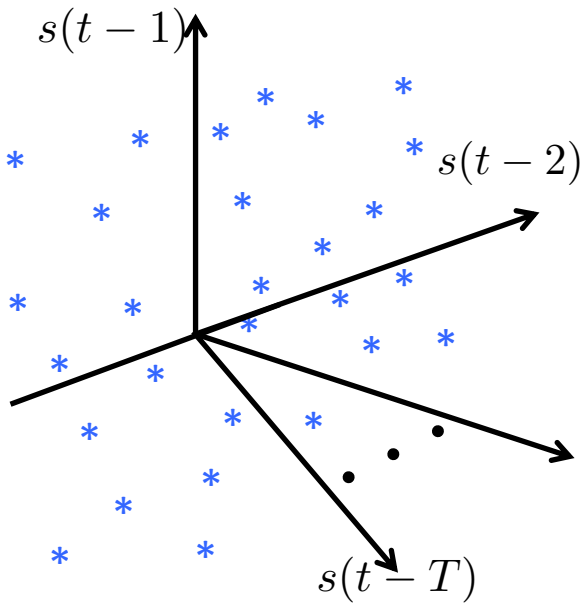
$$\{s(t-T)\cdots s(t-2)s(t-1)\}$$



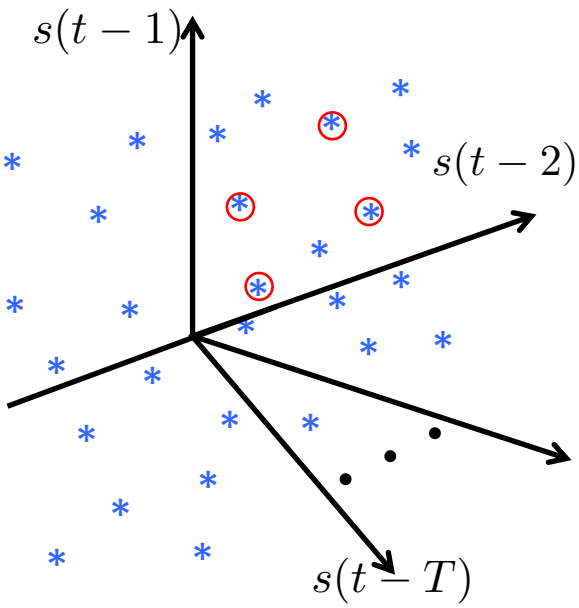
Any possible stimulus time-series is one point in stimulus space

Geometric view of STA

* presented stimuli

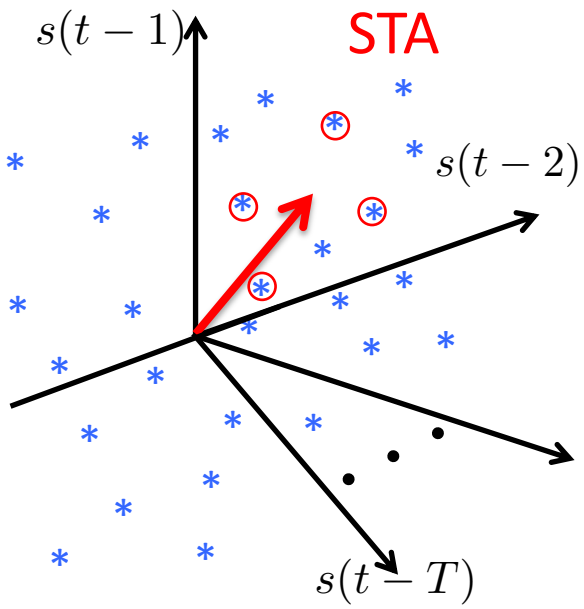


Geometric view of STA



* presented stimuli
* effective stimuli (evoked spike)

Geometric view of STA

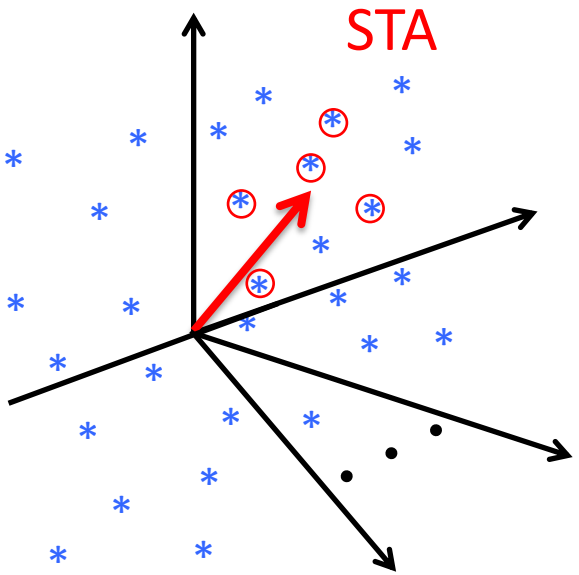


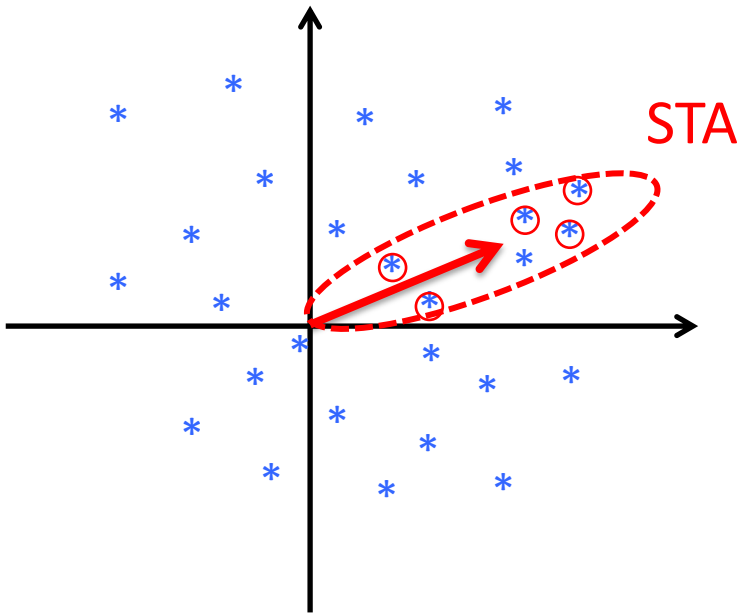
presented stimuli

effective stimuli (evoked spike)

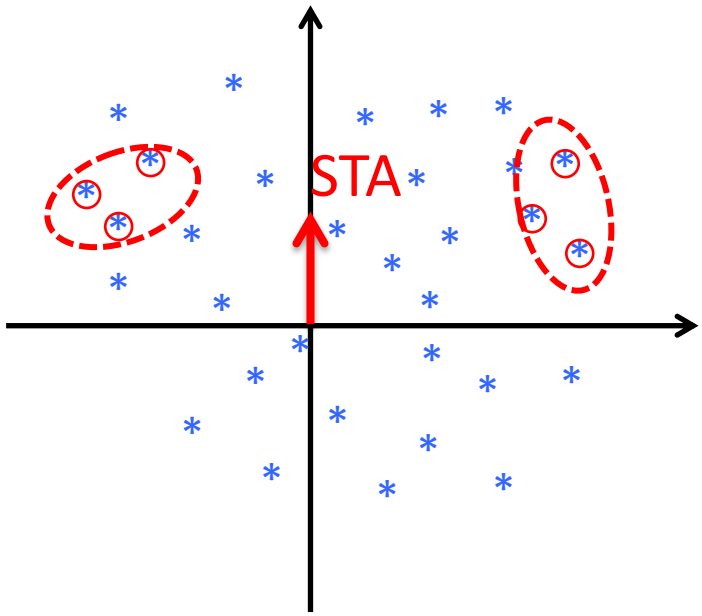
STA picks single direction in stimulus space

Geometric view of STA



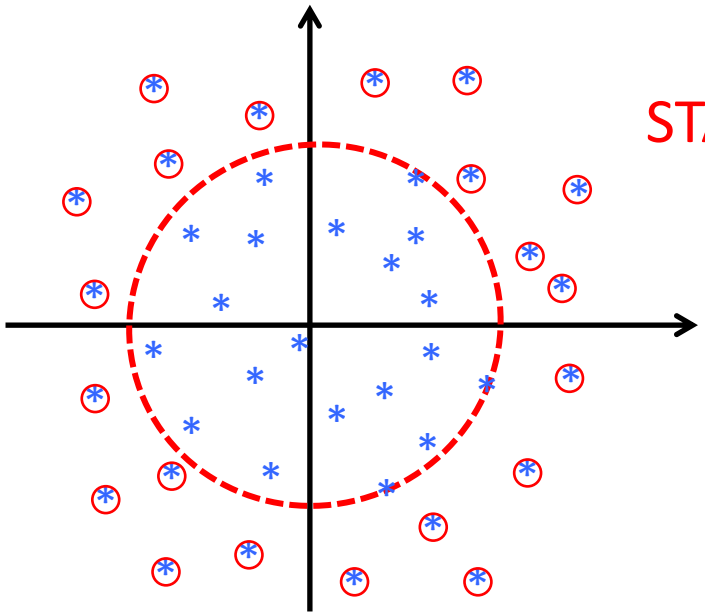


Geometric view of STA: when does it fail?



STA points in direction where stimuli were actually ineffective in producing spikes.

Geometric view of STA: when does it fail?



STA = 0

Example: motion energy model for complex cells in V1.

Same caution as correlation: measure of linear relationship between stimulus, response. If response is specific nonlinear function of stimulus, then STA may not be informative.

Summary: STA

- Simple/compact description of data.
- Extracting single “feature” of data.
- Linear feature; first term in Volterra expansion.
- Test: Prediction of response (encoding). Homework.