Decoding V1 Neuronal Activity using Particle Filtering with Volterra Kernels

Bayesian Decoding has been recently used to decode arm trajectories based on M1 neurons’ responses. Here we apply a similar technique to decode a visual stimulus, given the responses of V1 neurons. The algorithm, presented in detail, is a variant of particle filtering in which the hypotheses are predictions of the entire signal sequence for all the time steps in a trial.

**Experiment**

Movies of a sine wave grating in motion were presented to a floating Macaque monkey. Each trial was 2.2 seconds in length.

The effective input signal was the phase of the grating. Cosine was taken to make correlations. The steps of the grating’s movement were drawn from a low-pass filtered Gaussian distribution, to induce some temporal correlations.

Throughout each trial, the activity of a V1 neuron was recorded.

**Data**

For each cell, 400 distinct random trials were presented for training data, and 65-80 trials of some repeated sequence were obtained for the purposes of testing.

**Volterra kernels as the transfer function**

To recover the first and second order Volterra kernels, t, with X the signal and Y the response, H(x,y) = ∑ h τ x(t−τ) + ∑ h τ 1,τ 2 x(t−τ 1)x(t−τ 2)

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**Particle filtering decoder**

### Hypothesis distribution at time t

An hypothesis about the signal sequence is called a “track.” At any time step, each hypothesis is a signal

### Prediction by Volterra kernel filtering

For each hypothesis h(t), the convolution of the signal sequence and H gives an estimated neuronal response

### Likelihood by comparing predictions to PSTH

The neuronal PSTH is predicted to the predicted response of each hypothesis to assess its likelihood. The Pseudo-Correlation produces the pseudocorrelation. The “volterra” equation yields the hypothesis likelihoods.

### Distribution after resampling

After resampling, the distribution is generally better at approximating the neuronal response at time t, assuming the Volterra kernels provide a good approximation of the transfer function.

### Resampling based on the likelihoods

The hypotheses are resampled according to their likelihoods:

The weights, in this example, has been shifted toward a hypothesis which remains close to 1 when compared to the distribution in Panel C.

**Results**

At the left are typical reconstructions, chosen randomly from 33 cells tested. The particle filter reconstruction typically performs significantly better than the optimal linear decoder due to nonlinearity in the reconstruction.

The reconstructions have been done with 60-80 trials making up the PSTH, but average performance with as few as 8 trials making up a PSTH is about the same as with 60-80 trials.

Since the particle filter depends on the performance of the Volterra kernels in predicting the neuronal response, we can see that the error of the kernels is correlated with the error of the particle filter reconstructions.

**References**


