Adaptive Estimation of Nonlinear Response Functions in V1 with Gaussian Processes

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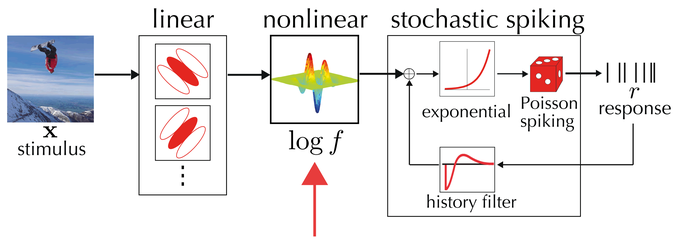
1. Neural characterization problem



Question: how to efficiently learn neural response nonlinearities in closed-loop experiments?

2. logGP-Poisson encoding model

generative model

MAP inference: $\mathbf{f}_{map} = \arg\max_{\mathbf{f}} \log p(\mathbf{f}|\mathbf{r}, \mathbf{X}, \theta)$

setting hyperparameters

- Set θ by maxizing marginal likelihood (Laplace approximation):

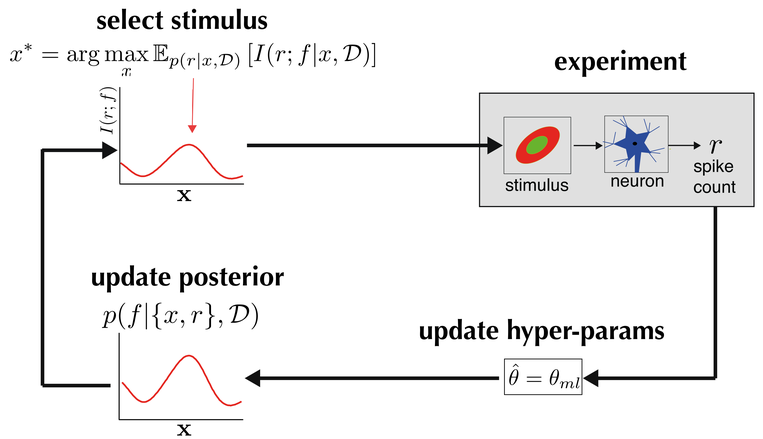
$$p(\mathbf{r}|\theta) = \int p(\mathbf{r}|\mathbf{f})p(\mathbf{f}|\theta)d\mathbf{f} \approx \frac{p(\mathbf{r}|X,\mathbf{f})\ln\mathcal{N}(\mu\ ,\ )}{\ln\mathcal{N}(\mathbf{f}_{map},\Lambda)}$$

Poisson likeli. log-normal } iterate! approx. log-normal posterior

- Numerical update of posterior & evidence for each θ : expensive!

3. Adaptive stimulus selection

- select stimulus $\mathbf{x}$ that maximizes expected information gain on each trial



- maximizing information = minimizing posterior uncertianty

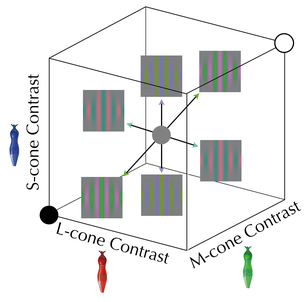
$$\arg\max_x \mathbb{E}_{p(r|x,\mathcal{D})}\left[I(r;f|x,\mathcal{D})\right] = \arg\min_x \mathbb{E}_{p(r|x,\mathcal{D})}\left[H(f|\mathcal{D},\{x,r\})\right]$$

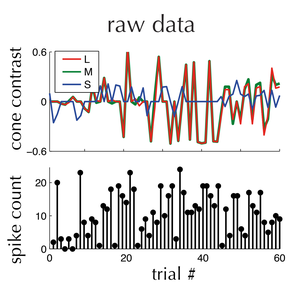
- reduction in entropy = $\mathbf{f}_{map}(x)\sigma_p^2(x)e^{\frac{\sigma_p^2(x)}{2}}$

posterior variance of log f

4. Experimental setup

- color-tuned neurons in macaque V1
- spectrally-modulated Gabor stimuli

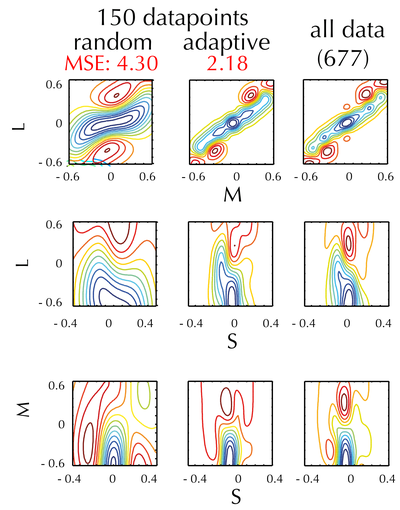




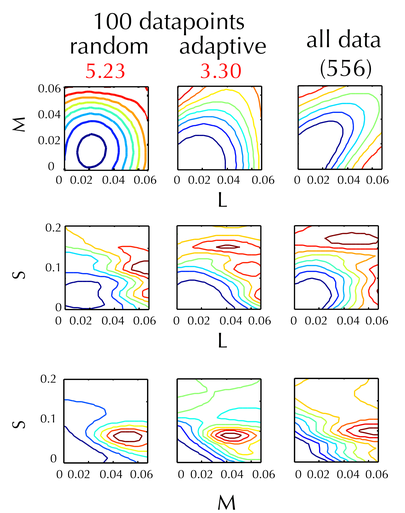
5. Results

- 2D slices of 3D nonliearity

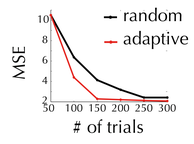
Cell1 :



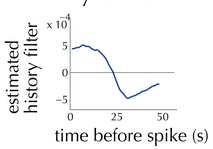
Cell2 :



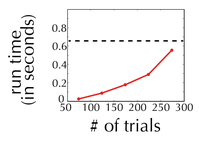
- MSE



- history effect



- run time



6. Conclusions

- flexible logGP-Poisson model for neural nonlinearities
- optimal design based on mutual information
- rapid learning of nonlinearities in closed-loop experiments

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