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State Space Models for Neural and Behavioral Data

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Abstract:

New recording technologies are revolutionizing neuroscience, allowing us to measure the spiking activity of hundreds to thousands of neurons in freely behaving animals. These technologies offer exciting opportunities to link brain activity to behavioral output, but they also pose statistical challenges. Neural and behavioral data are noisy, high-dimensional time series with nonlinear dynamics and substantial variability across subjects. I will present our work on state space models (SSMs) for such data. The key idea is that these high-dimensional measurements reflect the evolution of low-dimensional latent states, which shed light on how neural circuits compute and how natural behavior is structured. I will present our work on SSMs that disentangle discrete and continuous factors of variation in time series data, and I will show how we have used these tools to study how neural attractor dynamics maintain persistent internal states during social interaction, in collaboration with the Anderson Lab at Caltech. Finally, I will discuss how these experimental collaborations have motivated further improvements to our models and algorithms for nonlinear state space models. All together, these projects demonstrate how our advances in statistics and machine learning offer powerful new tools for gaining insight into the neural computations underlying naturalistic behavior.

Reading list:

- Nair, A., Karigo, T., Yang, B., Ganguli, S., Schnitzer, M. J., Linderman, S. W., Anderson, D. J., & Kennedy, A. (2023). An approximate line attractor in the hypothalamus encodes an aggressive state. *Cell*, *186*(1), 178–193. Paper bioRxiv
- Hu, A., Zoltowski, D., Nair, A., Anderson, D., Duncker, L., & Linderman, S. W. (2024). Modeling Latent Neural Dynamics with Gaussian Process Switching Linear Dynamical Systems. *Advances in Neural Information Processing Systems (NeurIPS)*.Paper arXiv
- Hu*, A., Smith*, H., & Linderman, S. W. (2025). SING: SDE Inference via Natural Gradients. *Advances in Neural Information Processing Systems (NeurIPS)*.arXiv Code