Thesis committee report

Sean Bittner, January 16, 2021

Summary: During my last thesis committee meeting in May, 2020, I presented progress on the emergent property inference (EPI) project. To refresh, EPI is a likelihood-free inference (LFI) method, that uses deep probability distributions (normalizing flows) to obtain flexible posterior approximations. I presented the EPI method and my work on neuroscientific applications of EPI, which come from this manuscript [1]. Our conclusion was that I should focus on a.) improving the science done with this method and b.) providing a comparative analysis between EPI and other LFI techniques. The advancements I've made since our last meeting are listed below.

Advancements since May, 2020:

1. **STG**: This introductory example based on an STG subcircuit [2] has been revisited: we introduced stochasticity to make a technical point, and changed the emergent property to improve the pedagogical value of the analysis.
2. **V1**: We now focus on how parameters of noise govern variability in the stochastic stabilized supralinear network (SSSN) [3] generalized to have inhibitory multiplicity.
3. **SC**: By request from our collaborators, we changed the modeling of network responses from winner-take-all to comparative decision making. Intriguingly, EPI inferred connectivities postdict optogenetic response properties published by the Brody Lab.
4. **RNNs**: We infer connectivities of low-rank RNN's exhibiting stable amplification using criteria defined in [4]. Here, we demonstrate the superior scaling properties of EPI compared to sequential Monte Carlo approximate Bayesian computation (SMC-ABC) [5] and sequential neural posterior estimation (SNPE) [6].

Each model in the paper was re-analyzed using the new epi software package, which takes advantage of modern advancements in normalizing flows.

In September, I had the opportunity to present our work on EPI at the Bernstein Conference Workshop on "Inferring and Testing Optimality in Perception and Neurons". Upon feedback from the committee and some final touches, we will resubmit our manuscript to eLife.

Professional ambitions: This past summer (June-Aug 2020) I had a research internship at Facebook Reality Labs (with the CTRL-Labs Science Team). I used recently developed techniques from automatic speech recognition to substantially improve EMG typing accuracy. I'm excited about the challenging research problems in BCI development, and I've applied for a Research Scientist position at Facebook with the CTRL-Labs group. I will be interviewed soon, the start date would be flexible, and my preferred graduation date is still May 2021. Here is my proposal for the thesis outline.

Proposed thesis outline

Title: Bridging data, theory, and experiment in computational neuroscience.
Chapter 1: Understanding movement generation using normative models:
tangling [7] and divergence [8].
Chapter 2: Amortizing statistical inference in exponential family models of neural activity [9].
Chapter 3: Inference in theoretical models of neural computation [1].

In our meeting, I'll summarize the latest advancements to the EPI project, and describe my contributions to the work listed in the thesis outline.

References

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[3] Guillaume Hennequin, Yashar Ahmadian, Daniel B Rubin, Máté Lengyel, and Kenneth D Miller. The dynamical regime of sensory cortex: stable dynamics around a single stimulus-tuned attractor account for patterns of noise variability. *Neuron*, 98(4):846–860, 2018.

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[5] Scott A Sisson, Yanan Fan, and Mark M Tanaka. Sequential monte carlo without likelihoods. *Proceedings of the National Academy of Sciences*, 104(6):1760–1765, 2007.

[6] Pedro J Gonçalves, Jan-Matthis Lueckmann, Michael Deistler, Marcel Nonnenmacher, Kaan Öcal, Giacomo Bassetto, Chaitanya Chintaluri, William F Podlaski, Sara A Haddad, Tim P Vogels, et al. Training deep neural density estimators to identify mechanistic models of neural dynamics. *bioRxiv*, page 838383, 2020.

[7] Abigail A Russo, Sean R Bittner, Sean M Perkins, Jeffrey S Seely, Brian M London, Antonio H Lara, Andrew Miri, Najja J Marshall, Adam Kohn, Thomas M Jessell, et al. Motor cortex embeds muscle-like commands in an untangled population response. *Neuron*, 97(4):953–966, 2018.

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[9] Sean R Bittner and John P Cunningham. Approximating exponential family models (not single distributions) with a two-network architecture. *ICML Workshop on Invertible Neural Networks and Normalizing Flows*, 2019.