Kenji Doya: Inference of Neural Circuit Connectivity form High-dimensional Activity Recording Data: A Survey

(Work with Ildefons Magrans de Abril, Jun-ichiro Yoshimoto)

Recent brain science initiatives around the world emphasize the use of high-throughput, systematic data acquisition and advanced computational technologies. Rich neural recording data allow us to assess neural information coding through correlative or decoding analyses with sensory, motor, or cognitive signals. However, in order to understand the operational principles of the brain, it is important to understand the circuit mechanisms that create particular information coding. As a part of Brain/MINDS

program in Japan, we performed a comprehensive survey of computational methods for inferring neural circuit connectivity from high-dimensional neural recording data, such as by multiple electrode arrays and optical imaging.

We first identified a number of biophysical and computational challenges in neural circuit identification. We then classified method into model-free methods using descriptive or information theoretic measures and model-based methods using a variety of generative models of neural signals combined with maximum likelihood and other statistical inference methods.

We present a map of existing studies along the axes of the challenges and the data processing pipeline to identify preferred methods and open challenges. Model-based methods have the benefit of reproducing neural circuit dynamics to produce simulated data. However, they tend to have more unknown parameters than model-free methods do, which poses a challenge in hyper-parameter estimation, especially when the sample size is limited. Addressing

nonstationarity caused by physiological states or instrumentation methods is an important practical issue. Another major challenge is the inference of unobserved external inputs and hidden neurons.