Efficient Signal Processing in Random Spiking Networks that Generate Variability

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Source of cortical variability and its influence on signal processing remain an open question. We address the latter, by studying two types of balanced random networks of quadratic integrate-and-fire neurons that produce irregular spontaneous activity patterns: (a) a deterministic network with strong synaptic interactions that actively generates variability by chaotic dynamics and (b) a stochastic network that has weak synaptic interactions but receives externally generated noise. These networks of spiking neurons are analytically tractable in the limit of a large network-size and channel-time-constant. Despite the difference in their sources of variability, spontaneous activity patterns of these two models are indistinguishable unless majority of neurons are simultaneously recorded. We characterize the network behavior with dynamic mean field analysis and reveal a single-parameter family that allows interpolation between the two networks, sharing nearly identical spontaneous activity. Despite the close similarity in the spontaneous activity, the two networks exhibit remarkably different sensitivity to external stimuli. The difference between the two networks is further enhanced if input synapses undergo activity-dependent plasticity, producing significant difference in signal to noise ratio. We show that, this difference naturally leads to distinct performance while integrating spatio-temporally distinct signals from multiple sources. Unlike its stochastic counterpart, the deterministic chaotic network activity can serve as a reservoir to perform near optimal Bayesian integration and Monte-Carlo sampling from the posterior distribution. We describe implications of the differences between deterministic and stochastic neural computation on population coding and neural plasticity. ･･････････････End