

RESEARCH ARTICLE

Optimal noise level for coding with tightly balanced networks of spiking neurons in the presence of transmission delays

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Abstract

Neural circuits consist of many noisy, slow components, with individual neurons subject to ion channel noise, axonal propagation delays, and unreliable and slow synaptic transmission. This raises a fundamental question: how can reliable computation emerge from such unreliable components? A classic strategy is to simply average over a population of N weakly-coupled neurons to achieve errors that scale as $1/\sqrt{N}$. But more interestingly, recent work has introduced networks of leaky integrate-and-fire (LIF) neurons that achieve coding errors that scale superclassically as $1/N$ by combining the principles of predictive coding and fast and tight inhibitory-excitatory balance. However, spike transmission delays preclude such fast inhibition, and computational studies have observed that such delays can cause pathological synchronization that in turn destroys superclassical coding performance. Intriguingly, it has also been observed in simulations that noise can actually improve coding performance, and that there exists some optimal level of noise that minimizes coding error. However, we lack a quantitative theory that describes this fascinating interplay between delays, noise and neural coding performance in spiking networks. In this work, we elucidate the mechanisms underpinning this beneficial role of noise by deriving analytical expressions for coding error as a function of spike propagation delay and noise levels in predictive coding tight-balance networks of LIF neurons. Furthermore, we compute the minimal coding error and the associated optimal noise level, finding that they grow as power-laws with the delay. Our analysis reveals quantitatively how optimal levels of noise can rescue neural coding performance in spiking neural networks with delays by preventing the build up of pathological synchrony without overwhelming the overall spiking dynamics. This analysis can serve as a foundation for the further study of precise computation in the presence of noise and delays in efficient spiking neural circuits.

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Oscillations in Neural Systems Daniel S. Levine,Vincent R. Brown,Timothy Shirey,1999-09-01 This book is the fourth in a series based on conferences sponsored by the Metroplex Institute for Neural Dynamics MIND an interdisciplinary organization of Dallas Fort Worth area neural network professionals in both academia and industry This topic was chosen as the focus for this special issue because of the increasing interest by neuroscientists and psychologists in both rhythmic and chaotic activity patterns observed in the nervous system Neither the mathematical structure of neural oscillations nor their functional significance is precisely understood There are a great many open problems in both the structure and function of neural oscillations whether rhythmic chaotic or a combination of the two and many of these problems are dealt with in the chapters of this book *The Informed Vision* David Hawkins,2002 An education classic is back in print Fifteen seminal essays explore how children develop their understanding of the world around them

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