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BAYESIAN PHYSICS-INFORMED NEURAL NETWORKS FOR CURVE ESTIMATIONS IN EXCITABLE MEDIA

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ABSTRACT

Strengthduration curves characterize the relationship between stimulus duration and the minimal strength required to trigger excitation, offering critical insight into the excitability and safety margins of excitable systems [1]. While these curves can, in principle, be derived analytically, such derivations are typically intractable except in a few highly idealized cases. As a result, constructing them often relies on direct numerical simulations, which become computationally demanding in multi-component systems or when the governing operators are not self-adjoint. To address these challenges, we introduce a Bayesian physics-informed neural network framework as an alternative approach for learning the entire strengthduration profile. Our method embeds the reactiondiffusion dynamics directly into the networks loss function, ensuring adherence to known biophysical laws, and treats the critical threshold curve as a hidden dependency learned during training. We employ Hamiltonian Monte Carlo to sample the posterior distribution of network [2] and threshold parameters, yielding wellcalibrated credible intervals that outperform variational and dropoutbased uncertainty estimates. A single Bayesian PINN model yields a smooth, continuous threshold curve with principled uncertainty estimates, enabling efficient exploration of excitability across parameter regimes. By combining the data efficiency and interpretability of physics-informed neural networks with the rigor of Bayesian inference [3, 4], this framework enables rapid discovery while providing robust uncertainty quantification, offering a flexible tool for investigating threshold phenomena in reactiondiffusion systems and related contexts. Overall, the Bayesian PINN achieves accurate, continuous estimates of strengthduration relationships and furnishes well-calibrated uncertainty bands, making it a reliable and interpretable tool for probing threshold phenomena in complex excitable systems.

***K*eywords** strengthduration · Bayesian · PINN · Monte Carlo · reaction-diffusion · threshold · credible interval

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