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Toy Introduction to Epidemiology-Informed Neural Networks (EINNs) with Application

The integration of mechanistic modeling and machine learning has the potential to revolutionize the way we understand complex biological systems. Particularly, the development of Informed Neural Networks (INNs), a class of hybrid models that embed domain-specific knowledge, such as differential equations, into the neural network architecture, has attracted many researchers recently. Epidemiology-Informed Neural Networks (EINNs) incorporate domain-specific knowledge from disease dynamics (e.g., differential equation models, compartmental models like SIR, vector-host interactions, etc.) into their architecture, loss functions, or training process. The loss function that is minimized during training is the combined loss of the data and the DE residuals. This method helps to improve learning, prediction accuracy, interpretability, and parameter estimation, particularly in scenarios where data is sparse or noisy. In this talk, I will quickly introduce the foundations of EINNs. I will then present some results from our study that we trained an EINN on synthetic data derived from an SI-SIR model designed for Avian influenza and show the model's accuracy in predicting extinction and persistence conditions. In the method, a twelve-layer hidden model was constructed with sixty-four neurons per layer, and the ReLU activation function was used. The network is trained to predict the time evolution of five state variables for birds and humans over $50,000$ epochs. The overall loss is minimized to 0.000006, characterized by a combination of data and physics losses, enabling the EINN to follow the differential equations describing the disease progression.