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Integration of mechanistic epidemiological models with AI for understanding and predicting avian influenza dynamics

Avian influenza continues to pose significant challenges to animal and public health, highlighting the need for mathematical and computational frameworks that can capture complex transmission dynamics and support reliable epidemic prediction. Traditional mechanistic models, formulated using differential equations, provide valuable insights into disease transmission, persistence, and control. However, integrating these models with heterogeneous and potentially incomplete epidemiological data remains challenging. Recent advances in artificial intelligence (AI), particularly physics-informed neural networks (PINNs) and disease-informed neural networks (DINNs), offer promising approaches for combining the interpretability of mechanistic models with the flexibility of deep learning.

In this talk, we discuss AI-integrated mechanistic modelling approaches for understanding and predicting avian influenza dynamics, with particular emphasis on DINNs. Building on our recent work, we develop a disease-informed deep learning framework based on a coupled SI bird and SIR human transmission model. The framework incorporates the governing epidemiological differential equations into the neural network training process through a loss function combining observational data fitting and mechanistic constraints. Using synthetic epidemiological data, we demonstrate the ability of the DINN to reconstruct infection trajectories, estimate model parameters, and capture disease extinction and persistence under different transmission scenarios.

Our numerical investigations highlight the influence of neural network architecture and training configurations on parameter estimation accuracy and predictive performance. We conclude by discussing opportunities and challenges in extending AI-informed mechanistic models to real-world avian influenza. This work illustrates the potential of integrating mathematical epidemiology and deep learning to advance data-informed epidemic forecasting within a One Health framework.