CRUNCH Seminars at Brown, Division of Applied Mathematics

Friday - July 7, 2023

Deep Data Driven Neural Networks for Learning Dynamics Of COVID-19 Epidemic Models

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We present three deep-learning methods to analyze different COVID-19 epidemic models. These three methods are inspired by physics-informed neural network (PINN). The first method, an epidemiology-informed neural network, is developed to learn the model parameters and dynamics of a deterministic vaccine efficacy model. Data-driven simulations and error metrics confirm that vaccinating more people curtails the spread of the disease. Data-driven simulations of a hybrid approach comprising residual and recurrent neural networks show that the ResNet-GRU hybrid is superior. In the second method, we learn the dynamics of the stochastic vaccine efficacy model by developing a stochastic epidemiology-informed neural network (SEINN). This method involves discretizing the system of stochastic differential equations using Euler-Murayama and encoding it as a loss function. The SEINN integrates a regularization parameter to enhance training accuracy. Subsequently, this second method aims to investigate the superiority of stochastic models over deterministic ones. Our findings show that stochastic models outperform their deterministic counterparts based on their error metrics. Finally, we examine the impact of stochasticity and vaccination on nonlinear incidence rates. The behavior-epidemiology-informed neural network (BEINN) is the third method. It learns an explicit compliance rate that changes over time and identifies the critical epidemiological parameters of a behavioral epidemic model. This third algorithm incorporates behavioral constraints, attention mechanism, and the regularization parameter to improve training precision. This method aims to analyze how social and behavioral factors impact disease dissemination. The computational analysis of BEINN regarding sensitivity, overfitting, and computational time shows the effectiveness and robustness of the third method. The epidemiological importance of this work includes the following: the outcome of the three methods can help public health officials develop effective vaccination and mitigation strategies by considering randomness in the model and the variability of human behavior in transmitting contagious diseases. We apply these three proposed methods to the spread of COVID-19 in Tennessee. The third methodology is employed to analyze the transmission of COVID-19 in the states of New York and Michigan.