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COVID-19 dynamics across the US: A deep learning study of human mobility and social behavior

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This paper presents a deep learning framework for epidemiology system identification from noisy and sparse observations with quantified uncertainty. The proposed approach employs an ensemble of deep neural networks to infer the time-dependent reproduction number of an infectious disease by formulating a tensor-based multi-step loss function that allows us to efficiently calibrate the model on multiple observed trajectories. The method is applied to a mobility and social behavior-based SEIR model of COVID-19 spread. The model is trained on Google and Unacast mobility data spanning a period of 66 days, and is able to yield accurate future forecasts of COVID-19 spread in 203 US counties within a time-window of 15 days. Strikingly, a sensitivity analysis that assesses the importance of different mobility and social behavior parameters reveals that attendance of close places, including workplaces, residential, and retail and recreational locations, has the largest impact on the basic reproduction number. The model enables us to rapidly probe and quantify the effects of government interventions, such as lock-down and re-opening strategies. Taken together, the proposed framework provides a robust workflow for data-driven epidemiology model discovery under uncertainty and produces probabilistic forecasts for the evolution of a pandemic that can judiciously inform policy and decision making. All codes and data accompanying this manuscript are available at https://github.com/PredictiveIntelligenceLab/DeepCOVID19.