Universal differential equations for infectious disease modelling

The ongoing covid-19 pandemic has seen a rise in infectious disease modelling. Computational models have been at the heart of political decision-making and have been utilised by public health authorities in almost all countries. Such models can be used in order to make predictions about the number of cases or hospital admissions in the near future of the pandemic, and also provide a tool for evaluating hypothetical interventions such as lockdowns.

A common framework for modelling disease transmission is compartmental models that describe how the number of individuals in pre-determined compartments change over time using a set of coupled ordinary differential equations (ODEs). One example is the SIR-model, which divides the population into a Susceptible, Infected and Recovered compartment. The rate at which people become infected in this model depends on the rate at which people interact, known as the contact rate.

A particular difficulty of pandemic modelling is that the contact rate is time-dependent and affected by e.g. public health recommendations and societal trends. One way of improving model accuracy is to include time series data that correlates with the contact rate, such as mobility data from mobile phones or data from public transport. In a previous article we have shown that this type of data can improve predictions of hospital admissions [1].

The standard approach for compartmental models is to specify a functional form of the system of ODEs that depend on a number of parameters that are estimated by comparing the model output (e.g. hospital admissions/week) to the actual outcome. However, the functional forms are often poorly grounded in theory or observation.

A complementary approach is to make use of Universal Differential Equations (UDEs) where the right hand sides of the ODEs are represented using a deep neural network [2]. In this setting one does not have to specify how mobility data affects disease transmission. Instead this emerges as the neural network is trained on outcome data.

The aim of this project is incorporate a number of mobility measures into an SEIR-model represented as a set of UDEs and investigate if this approach performs better than the classical ODE approach [1].

Contact person: Philip Gerlee, gerlee@chalmers.se

References

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