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Real-time inference and risk-prediction for emerging infectious diseases

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The nature of emerging infectious diseases implies that the characteristics of an outbreak cannot fully be understood in advance of an incursion. For this reason, control policies are necessarily based on prior expectation of how a new epidemic might evolve given experience of past outbreaks, and the behaviour of the disease in other populations. However, due to changes in the host, pathogen, and environment over time, a new outbreak may not behave as expected based on prior information alone. In trying to gain a more accurate insight into how a future disease outbreak might spread through a population, mathematical simulation modelling has become a popular and established tool. Yet such simulations rely on certain parameters in order to drive them, and estimating appropriate values in advance of an epidemic has been the major difficulty in the predictive credibility of such approaches.

The obstruction to classical approaches in estimating model parameters has been that of latent data: i) an infection time is never directly observed, it is only when the individual shows signs of disease that the infection is detected; ii) if we wish to make inference on an epidemic in progress, we must account for any infected-but-undetected individuals in the population or risk biasing our estimates.

This talk will describe a generic Bayesian RJMCMC-based framework for analysing epidemics that performs inference on disease infection rates via specified transmission mechanisms, and imputes the latent data. Since this framework is designed to be used during an epidemic, the necessary methodological enhancements required to accelerate the algorithms for real-time use will also be described.

Two examples - one of a potential Highly Pathogenic Avian Influenza outbreak in UK poultry, and the other of the foot and mouth disease outbreak in the UK in 2007 - show how this framework is applied to different disease outbreak scenarios, and how the resulting Bayesian posteriors can be used in conjunction with simulation and GIS techniques to provide information for decision-making during epidemics.