Advanced Topics in Medical Modeling

CrystalCast Toolset – Empowering Decision Making From Uncertain Disease Forecasts

Ian Hall, Manchaster University and Public Heather England
Daniel Silk, Dstl
Joe Gillard, Dstl
Veronica Bowman, Dstl

There are many models and techniques for disease forecasting over a huge range of spatial and temporal scales, using a wealth of potential data streams. This results in many different predictions of disease spread and effects on a population, with no clear indication of the likelihood of any one outcome. In combination with a range of possible intervention strategies, this leaves the decision maker information rich, but knowledge poor. The aim of the CrystalCast Toolset is to bring these disparate models and data streams together in a seamless, rigorous mathematical framework supported by a fully interactive, state of the art, visualization system. To that end, CrystalCast provides the ability to interrogate, manipulate and, crucially, to optimize, the potential courses of action. In the event of a disease outbreak, decision makers will need to determine the medical intervention that minimizes the impact on Warfighter health, whilst maintaining force readiness and operational effectiveness. In practice, the intervention strategy will be a complex trade-off between competing objectives, subject to logistical and economic constraints, with success dependent upon the specific dynamics of the disease within the population. Decision makers can be supported by algorithms that identify the courses of action that provide a mathematically optimal trade-off, given the disease model forecasts. However, until now, such an analysis has been prohibitively slow and required expert interpretation of the complex underlying assumptions and uncertainties. CrystalCast optimizes the potential courses of action in operationally relevant run-times through the use of machine learning; specifically the use of emulators; statistical meta-models that are computationally cheap to run and may be constructed from a small number of simulations from the original model. Crucially, the CrystalCast team have developed a novel theory for the emulation of chains of models, which consist of multiple modules (dispersion, dose-response, epidemiology and intervention) where the output of one model is used as input to the next. This new method has been shown to significantly improve prediction accuracy, and reduce the computational overhead of training the emulator. CrystalCast utilizes a visualization process developed to empower non-experts to make decisions based on uncertain information. The process is powered by two important innovations: Firstly, the predictions and uncertainties from alternative disease models are fused into a single coherent forecast using a novel model combination technique. Secondly, the combined forecast and optimal courses of action are communicated through a set of simple and intuitive displays that represent the cutting edge in uncertainty visualization, and essentially automate the expert interpretation and communication of disease model outputs. The speed and interpretability of CrystalCast allows rapid impact assessment of medical plans and interventions for the Warfighter. By automatically combining multiple disease forecasts into coherent actionable information, the capability enables truly evidence based decisions under uncertainty.