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ABSTRACT

Optimal sequential management decisions for influenza outbreaks

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Objective

This abstract highlights a methodology to build optimal management policy maps for use in influenza outbreaks in small populations.

Introduction

Management policies for influenza outbreaks balance the expected morbidity and mortality costs versus the cost of intervention policies under outbreak parameter uncertainty. Previous approaches have not updated parameter estimates as data arrives[1] or have had a limited set of possible intervention policies.[2] We present a methodology for dynamic determination of optimal policies in a stochastic compartmental model with sequentially updated parameter uncertainty that searches the full set of sequential control strategies.

Methods

We model small population influenza outbreaks using a stochastic SIR-model with parameters controlling the S→I and I→R transition rates. The full posterior distribution for the parameters is sequentially updated at each data point, for example, Figure 1.

Isolation and vaccination can be initiated at any time to modify the S→I transition rate and create an S→R path, respectively. The total cost for an outbreak is the sum of the costs for infected individuals as well as ongoing and fixed costs for intervention strategies that depend on when each intervention is initiated. Combining the techniques of dynamic programming and regression Monte Carlo, we use simulation techniques to build an optimal policy map for all possible future outbreak scenarios. Once an outbreak has begun, real-time decisions are made by calculating current parameter and state estimates and then consulting the policy map.

Results

As an illustration of our methodology, we consider the case of a flu outbreak in an English boarding school described in[3] and recently used by Merl D *et al.*[2] As our initial state, we take two infected and 761 susceptible individuals. In Table 1, we compare the cost of our dynamic strategy to simpler strategies over random outbreak realizations.

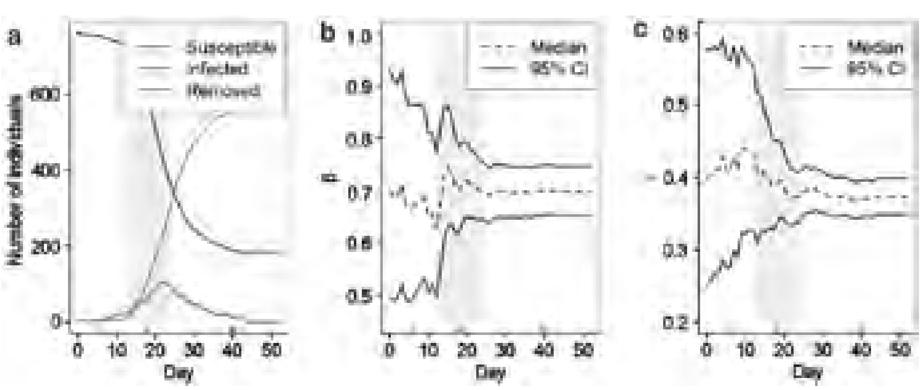

Figure 1 A realization of the stochastic SIR model along with sequential point wise medians and 95% credible intervals for sequential inference on model parameters.

Table 1 Average cost comparison of the dynamic control (Dyn) strategy versus no control (NC), isolation always (Iso), threshold (Thr) and fixed-date (F-D) for various infected cost structures, $c(i) = i + 0.1(\max(i-I,0))^2$

I	*NC*	*Iso*	*Thr*	*F-D*	*Dyn*
∞	1030	1400	1091	942	876
75	3350	1440	1091	1183	886
50	4950	1515	1091	1378	902
25	7250	1666	1097	1667	931

Conclusion

We have built novel methodology to find optimal policy maps for dynamic risk management of flu outbreaks in a stochastic framework with parameter uncertainty. The methodology accounts both for stochastic interactions between individuals during outbreaks as well as uncertainty about the outbreak parameters that are important for policy makers. The simulation-based control algorithm computes an approximately optimal adaptive and dynamic management strategy, which creates a full policy map across all possible outbreak scenarios.

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References

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