Modeling Optimal Intervention Strategies for Decision-Support in Epidemic Management

Extended Abstract

Andrea Yañez
Insight Centre for Data Analytics, NUI Galway
andrea.yanez@insight-centre.org

Conor Hayes
College of Engineering and Informatics
conor.hayes@insight-centre.org

ABSTRACT

In preparation for an epidemic, the understanding of disease dynamics and the effectiveness of intervention strategies to contain disease spread is critical. In order to decide which interventions to implement, decision makers need to analyze a large number of scenarios and variables. These tasks can be overwhelming. For this reason, our research is focused on finding optimal intervention strategies for containing disease spread, and in this way, to support the decision-making process in an epidemic scenario.

1 INTRODUCTION

In the globalized world, several aspects of our living conditions have improved, thus allowing increase in life expectancy. However, infectious disease spread remains as a threat. Emergence or re-emergence of a pathogen can suddenly increment the number of ill people over those expected in an area (epidemic) or around the globe (pandemic). In the last decade, diseases such as Malaria, AIDS, Ebola, among others; have been causing millions of deaths. Thereby, it is crucial to discover what interventions may be applied to contain the disease spread. An incorrect or untimely decision can have negative consequences such as an increase in mortality and morbidity rate and generate economic loss. In this scenario, decision-makers need to determine which interventions/policies are critical to mitigate the epidemic.

2 RESEARCH PROBLEM

The decision of how to contain the spread of a disease poses a significant challenge for governments and public health officials. First, decision makers need to understand the dynamics of the disease, then predict its course to be able to develop mitigation policies for controlling it. Such situations require a considerable effort because it is necessary to examine all possible scenarios, explore a large space of outcomes, and determine optimal policies. These policies must be in accordance with the objectives of the decision makers such as reducing the number of people infected, reduce the mortality and morbidity rate, or decrease the overall cost of the epidemic. Hence, the decision to select the best policies result in a large-scale problem where finding the best policies is difficult.

3 RELATED WORK

To study the disease spread and evaluate the effects of different interventions (e.g. antiviral prophylaxis, vaccination, social distancing, isolation) several models have been proposed [1–3]. Our related works address the following question: How to find optimal intervention strategies that are critical for the success of epidemic control?

Perlroth et al. [1], represented an influenza outbreak and different levels of severity (mild, moderate and severe) in an agent-based social network model in conjunction with an economic model to estimate the effectiveness of 48 different strategies based on 6 interventions. The results indicated that the strategy suggested depends on the severity level of the epidemic. Yaesoubi et al. [2], proposed an optimal dynamic policy using a Markov Decision Process model maximizing the net monetary benefit of the population. The policies generated support the policy maker to: determine if social distance interventions should be applied given the number of susceptible and infected individuals, and determine in what way to allocate vaccines when they become accessible. In a nutshell, approaches usually use techniques from different fields such as dynamic programing, economic analysis and simulation optimization in order to find optimal strategies.

4 RESEARCH APPROACH

In our previous work, PandemCap was proposed. PandemCap [3], is an interactive visualization tool that can be used by public health officials to analyze the impact of applying interventions for a given disease by selecting them manually. However, PandemCap does not suggest the best strategy to contain the disease spread. In our work, we explore how to obtain the best intervention strategies that satisfy decision-maker goals. Our approach is divided into two components: the Disease model and the Optimization approach. The first component gives us all possible intervention strategies given a certain characteristic of the disease. Because this space is large we can not use an exhaustive algorithm to search for the optimal policy. Instead, we add a second component to the Optimization approach that searches large sets of intervention strategies from the current state to a desirable goal state to find the optimal sequence of intervention that give the best outcome. This sequential decision-making problem is modeled as a Markov Decision Process.

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