Chapter 11
Simulating the Spread of an Epidemic in a Small Rural Kansas Town

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**ABSTRACT**

Substantial research has been dedicated to simulating the spread of infectious diseases. These simulation models have focused on major urban centers. Rural people have drastically different interaction and travel patterns than urban people. This paper describes a generic simulation package that can simulate the spread of an epidemic on a small rural town. This simulation package is then used to test the effectiveness of various mitigation strategies.

**1. INTRODUCTION**

Epidemics have played and will play a critical role in human history. Advancing the understanding of how epidemics spread has numerous benefits including: improving healthcare systems, increasing life spans, and reducing the impact of biological warfare. Here, an epidemic is defined as an outbreak of a disease that spreads rapidly and widely.

Various epidemics have hampered society for centuries including such famous cases as the Bubonic Plague, Avian Flu, and SARS. Of particular interest to this paper is the 1918 Spanish Flu, because it began in rural Kansas near the location of this research. This virus spread to all corners of the earth and is estimated to have killed 50 million people (Taubenberger & Morens, 2006), which is more than double the death toll of World War I.

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Viruses and bacteria continue to evolve and grow stronger, providing new challenges for mankind. In 2007, a strain of evolved drug resistant staph infection spread to 94,000 people throughout the United States and killed 19,000 (Manier, 2007). It is clearly imperative for governmental agencies to understand how diseases spread and, more importantly, how to limit their spread.

After an outbreak occurs, the government is responsible for creating and enforcing a mitigation strategy. These mitigation strategies have immense social, ethical and economic impacts. Some previously used mitigation strategies include closing schools, establishing quarantines, limiting travel, radio and TV announcements, and encouraging healthy habits (washing hands, wearing masks, avoiding unnecessary contact, etc.) (CDC, 2010).

For years, epidemics have been modeled mathematically as a way to safely understand them (Gordis & Saunders, 2000; Rothman, 2002). Mathematically analyzing an epidemic typically requires the modeling of complex biological systems such as viruses, bacteria, parasites, and hosts. These models must mimic how the epidemic affects the individual with respect to age, sex, and recovery rate. In addition, it necessitates an understanding of how epidemics spread, which includes, how the disease is transmitted, what travel patterns that the subjects exhibit, and the geographical layout of the area.

Mathematical models of epidemics can be largely divided into two classes: host and spread. The host class models (Kumar, 2002; Olsson, 1996) focus on the effect of the disease on the individual, while the spread class models predict how diseases proceed through a group of individuals. The focus of this paper is on the spread of infectious diseases and the impact of mitigation strategies. Clearly, a fundamental understanding of how a disease spreads from host to host must be understood to provide an accurate dispersion model.

The most typical mathematical model for the spread of a disease is a state model. This model assumes that time is divided into periods and each individual is classified in a particular state for an entire period. The most basic state model is the SIR model, where each individual is classified in one of three states: susceptible, infectious, and recovered (Fuks et al., 2006; Newman, 2002; Ogren & Martin, 2000; Piqueira, Navarro, & Monteiro, 2005). From this model, researchers have branched out by adding new and more complex states, such as exposed and quarantined states (Cristea, Zaharia, Deutsch, Bunescu, & Blujdescu, 1992; Kolesin, 2007; Neal, 2008; Nuno, Castillo-Chaves, Feng, & Marcheva, 2008; Rosenberg, 1997; Yu, Luo, Gao, & Ai, 2006).

Many of these mathematical models have been used to derive interesting theoretical results, such as how fast a disease dies out. To determine these results, a typical assumption is that every individual is in direct contact with all other individuals. However, this underlying assumption is unrealistic in the real world; yet, with more realistic assumptions on how individuals interact, deriving nice theoretical results becomes challenging. Thus, many researchers have turned to simulation (Britton, Janson, & Martin-Lof, 2007; Huang, Hsieh, Sun, & Cheng, 2006; Guimaraes et al., 1979; Rvachev, 1968; Barrett, Eubank, & Smith, 2005).

This paper describes a simulation tool to analyze the spread of infectious diseases in a small rural town. This simulation models Clay Center, Kansas (Population 4,600) and is used to test various mitigation strategies. Computational results demonstrate that a rapid reaction from the government is vital to the containment of a disease and that the government should focus efforts on eliminating both contacts between individuals and the rate that an individual passes the disease to another individual.
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