Chapter 50
A Surveillance and Spatiotemporal Visualization Model for Infectious Diseases Using Social Network

Younsi Fatima-Zohra
University of Oran, Algeria & University of Lumière Lyon 2, France

Hamdadou Djamila
University of Oran, Algeria

Boussaid Omar
University of Lumière Lyon 2, France

ABSTRACT

In this paper, the authors propose a surveillance and spatiotemporal visualization system to simulate the infectious diseases spread which enables users to make decisions during a simulated pandemic. This system is based on compartment Susceptible, Exposed, Infected, and Removed (SEIR) model within a Small World network and Geographic Information System. The main advantage of this system is that it allows not only to understand how epidemic spreads in the human population and which risk factors promote this transmission but also to visualize epidemic outbreaks on the region's map. Experiments results reflect significantly the dynamical behavior of the influenza epidemic and the system can provide significant guidelines for decision makers when coping with epidemic diffusion controlling problems.

1. INTRODUCTION

According to the World Health Organization (WHO), infectious diseases are responsible for a quarter to a third of all deaths worldwide, it presents a significant morbidity and mortality burden on the population. Moreover, it is crucial to understand how a disease spreads in modern society and identify epidemic outbreak areas. Indeed, faced with such a threat, the society has to get ready in advance to react quickly and effectively if such outbreak is declared.

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Compartmental models are used extensively in analyzing the spread, and control of infectious diseases qualitatively and quantitatively. In these models, the entire population is divided into different compartments representing an epidemiological state which depends on the disease characteristics. However, transmission of the epidemic virus occurs as a result of person-person contact i.e. the contact between susceptible and infected individuals form a social network. To deal with this effect, the disease transmission should be modelled over complex networks in order to get the best understanding of epidemic. Analysis of real networks reveals the existence of Small World (SW) in many interaction networks, including networks of social contacts. For many infectious diseases, a SW network on an underlying regular lattice is a suitable simplified model for the contact structure of the host population. It is well known that the contact network plays an important role in both the short-term and the long-term dynamics of epidemic spread (Da Gama & Nunes, 2006). Moreover, SW is an attempt to represent realistically network contacts between individuals, because it is characterized by two important properties observed in many real-world networks: small diameter and high clustering coefficient. These characteristics have important implications in the context of epidemics: the high level of clustering means that most infection occurs locally, but short path lengths means that epidemic spreads through the network is rapid. Although the fact of epidemic spread is essentially a spatio-temporal phenomenon, health policy makers are, usually, in need for a tool that allows monitoring in space and time (spatiotemporal tool). The most classical tool for visualization of spatiotemporal information is a GIS (Geographic Information System). However, tracking dynamics of infectious diseases and detecting changes in a disease process are impossible without development and implementation of mathematical and social methodology dedicated to spatial-temporal disease surveillance which is not included in GIS. More recently, several authors have stressed the need for realistic models to include spatiotemporal structure which is known to be another essential ingredient of the dynamics of epidemic spread.

Indeed, in this paper, we propose and discuss a novel hybrid system (SEIRSW-GIS) based on a visualization tool for infectious disease surveillance. SEIRSW-GIS is, principally, based on compartment SEIR model within SW methodology to monitor the disease over time and GIS frameworks. The SW model adapts and extends the models for networks of social contacts proposed by (Watts & Strogatz, 1998). SW describes contacts that can result disease transmission between individuals and it defines distribution of degree for the contacts number that each susceptible individual has with other individuals in the community. The number of neighbors is known as their degree or connectivity and it is typically denoted by (k). Looking across the entire population, this measure is known as the connectivity distribution (or degree distribution). Traditionally, the SEIR compartment model concernes diseases characterised by an incubation period and applied in case of one strain of epidemic. Moreover, the SEIR model allows us to study the evolution of the epidemic over time by modelling and presenting the fourth state of the illness: Susceptible, Exposed, Infected, and Removed over time. The combined model SEIRSW aims to understand infectious disease dynamics in the communities and to identify the main characteristic of epidemic transmission by the control of its evolution over time. Moreover, it is used to examine social network effect to better understand the topological structure of social contact.

The key motivation of SEIRSW-GIS system is analysis and monitoring of the infectious diseases spread in a given system, for identifying risk factors and determining intervention approaches to the decision maker (public health officials). Hence, it allows increase shortcomings of the two models providing decision makers of public health an interactive and powerful geo-decision-making tool. Several studies have used differential equations to study the SW effect in compartment epidemic models. In the current

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