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A spatio-temporal Bayesian model for syndromic surveillance: properties and model performance

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Introduction

Syndromic surveillance uses syndrome (a specific collection of clinical symptoms) data that are monitored as indicators of a potential disease outbreak. Advanced surveillance systems have been implemented globally for early detection of infectious disease outbreaks and bioterrorist attacks. However, such systems are often confronted with the challenges such as (i) incorporate situation specific characteristics such as covariate information for certain diseases; (ii) accommodate the spatial and temporal dynamics of the disease; and (iii) provide analysis and visualization tools to help detect unexpected patterns. New methods that improve the overall detection capabilities of these systems while also minimizing the number of false positives can have a broad social impact.

Methods

In this paper, we propose an inference model for determining the location of outbreaks of epidemics in a network of nodes. In our setting, the network is the NC counties where the basic model incorporates spatial geographical relationships between the counties. The model is epidemiological, by choice, to process daily flu counts from the counties in order to infer when an outbreak of flu is present in a county that is distinguishable from background counts. The methodology incorporates Gaussian Markov random field (GMRF) and spatio-temporal conditional autoregressive (CAR) modeling.

Results

The methodology has some nice features including timely detection of outbreaks, robust inference to model misspecification, reasonable prediction performance as well as attractive analytical and visualization tool to assist public health authorities in risk assessment. Based on extensive simulation studies and synthetic data generated from a dynamic SIR model, we demonstrated that the model is capable of capturing outbreaks rapidly, while still limiting false positives.

Conclusions

In this paper, we have presented a new methodology that adapts the existing GMRF class of models to deal with spatio-temporal surveillance data. When the data are mainly spatial and coarsely discretized in time, simple models such as the CAR model will continue to be valuable for descriptive analysis. However, when data have a fine resolution in both the spatial and temporal dimensions, our model, which explicitly incorporates the directional nature of time by conditioning future events on past outcomes, is likely to be more insightful.

Keywords

Syndromic surveillance; spatio-temporal; Markov random field; conditional autoregressive

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