Bayesian Spatio-Temporal Methodology for Biosurveillance

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The complexity of spatio-temporal data in epidemiology and surveillance presents challenges such as low signal-to-noise ratio and generating high false positive rate for researchers and public health agencies. Central to the problem in the context of disease outbreaks is a decision structure that requires trading off false positives for delayed detections. We describe a novel Bayesian hierarchical model capturing the spatio-temporal dynamics in public health surveillance data sets. We further quantify the performance of the method to detect outbreaks by incorporating different criteria, including false alarm rate, timeliness and cost functions. Our data set is derived from emergency department (ED) visits for Influenza-like illness and respiratory illness in the Indiana Public Health Emergency Surveillance System (PHESS). The methodology incorporates Gaussian Markov random field (GMRF) and spatio-temporal conditional autoregressive (CAR) modeling. Features of this model include 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. Our numerical results show that the model captures salient spatio-temporal dynamics that are present in public health surveillance data sets, and that it appears to detect both "annual" and "atypical" outbreaks in a timely, accurate manner. We present visualizations that help make model output accessible and comprehensible to public health authorities. We use an illustrative family of decision rules to show how output from the model can be used to inform false positive and delayed detection tradeoffs.

Keywords: Syndromic surveillance; spatio-temporal data; conditional autoregressive; Influenza-like illness.