Multidimensional Tensor Scan for Drug Overdose Surveillance

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Objective
We present the multidimensional tensor scan (MDTS), a new method for identifying emerging patterns in multidimensional spatio-temporal data, and demonstrate the utility of this approach for discovering emerging geographic, demographic, and behavioral trends in fatal drug overdoses.

Introduction
Drug overdoses are an increasingly serious problem in the United States and worldwide. The CDC estimates that 47,055 drug overdose deaths occurred in the United States in 2014, 61% of which involved opioids (including heroin, pain relievers such as oxycodone, and synthetics). Overdose deaths involving opioids increased 3-fold from 2000 to 2014. These statistics motivate public health to identify emerging trends in overdoses, including geographic, demographic, and behavioral patterns (e.g., which combinations of drugs are involved). Early detection can inform prevention and response efforts, as well as quantifying the effects of drug legislation and other policy changes.

The fast subset scan detects significant spatial patterns of disease by efficiently maximizing a log-likelihood ratio statistic over subsets of data points, and has recently been extended to multidimensional data (MD-Scan). While MD-Scan is a potentially useful tool for drug overdose surveillance, the high dimensionality and sparsity of the data requires a new approach to estimate and represent baselines (expected counts), maintaining both accuracy and efficient computation when searching over subsets.

Methods
The multidimensional tensor scan (MDTS) is a new approach to subset scanning in multidimensional data. In addition to detecting the spatial area (subset of locations) and time window affected by an emerging outbreak, MDTS can also identify the affected subset of values for each observed attribute. For example, given the drug overdose surveillance data described below, MDTS can identify the affected genders, races, age ranges, and which drugs were involved. MDTS finds subsets of the attribute space with higher than expected case counts, first using a novel tensor decomposition approach to estimate the expected counts. MDTS then iteratively applies a conditional optimization step, optimizing over all subsets of values for all other attributes, and using the linear-time subset scanning property to make each conditional optimization step computationally efficient. The resulting approach has high power to detect and characterize emerging trends which may only affect a subset of the monitored population (e.g., specific ages, genders, neighborhoods, or users of particular combinations of drugs).

Results
We used MDTS to analyze publicly available data from the Allegheny County, PA medical examiner’s office and to detect emerging overdose patterns and trends. The dataset consists of 2000 fatal accidental drug overdoses between 2008 and 2015. For each overdose victim, we have date, location (zip code), age, decile, gender, race, and the presence/absence of 27 commonly abused drugs in their system. The highest-scoring clusters discovered by MDTS were shared with Allegheny County’s Dept. of Human Services and their feedback obtained.

Conclusions
Retrospective analysis of Allegheny County overdose data suggests high potential utility for a prospective overdose surveillance system, which would enable public health users to identify emerging patterns of overdoses in their early stages and facilitate targeted and effective health interventions. The MDTS approach can also be used for other multidimensional public health surveillance tasks, such as STI surveillance, where the patterns or outbreaks of interest may have demographic, geographic, and behavioral components.

Keywords
event detection; outbreak detection; subset scan; drug overdose surveillance

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