Forecasting Heroin Overdose Occurrences from Crime Incidents

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Motivation

- Opioid overdose rates in the United States have increased at an alarming rate since the past decade.
- Forecasting opioid overdose occurrences may enhance the overdose surveillance and identify the areas in need of prevention effort.
- Prior works suggested different types of links between the overdose occurrences and criminal activities, such as financial motives and common causes.

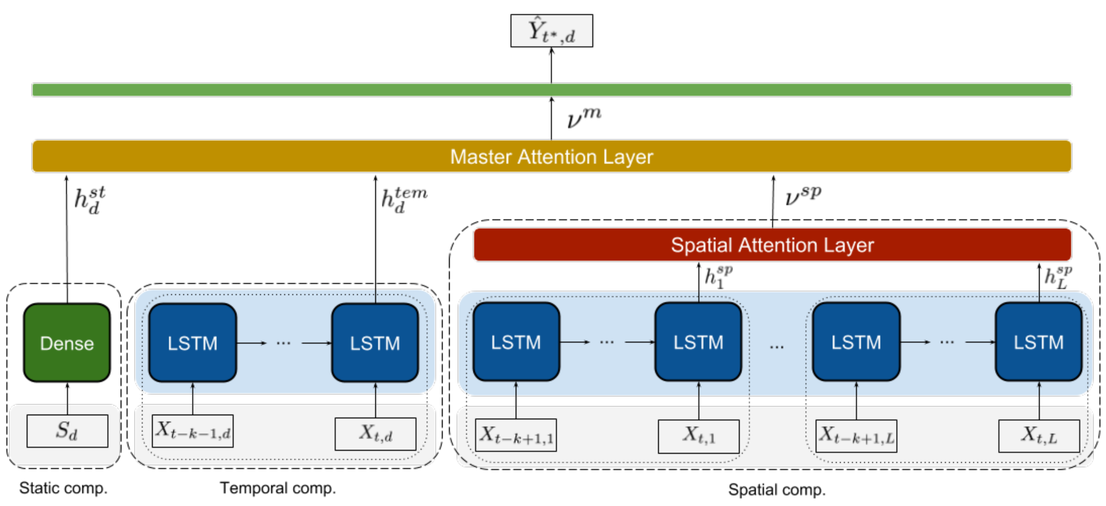
Aim: explore forecasting capability of heroin overdose occurrences using real-time crime data:
- model the spatiotemporal patterns of the crime incidents to forecast future heroin overdose occurrences,
- identify more informative static and dynamic features on forecasting heroin overdose occurrences,
- discover the predictive hotspot neighborhoods,
- examine the contribution of local and global crime dynamics, and static features on forecasting future heroin overdose occurrences.

Achieve all of them with a single, end-to-end trainable model.

Data and Features

- Cincinnati Heroin Overdose Dataset
  - Monthly overdose incidents between August 2015 – May 2018
  - Used as target variables employed in forecasting
- Cincinnati Police Data Initiative Crime Incidents Dataset
  - Monthly crime incidents between August 2015 – May 2018
    - Theft
    - Burglary / Breaking – Entering
    - Robbery
    - Aggravated assault
    - Rape
    - Minor crimes
    - Unauthorized use
  - Used as dynamic features to forecast opioid overdose
- US Census 2010 Data (Cincinnati Statistical Neighborhood Approximations)
  - Population, demographics (gender, race) and economic status (low median income, per capita income, poverty)
  - Used as static features to forecast opioid overdose

Architecture



- Static component: Encodes static features of the target location.
- Temporal component: Encodes local crime dynamics of the target location.
- Spatial component: Encodes spatiotemporal crime dynamics of all locations.
- Spatial attention layer: Identifies the predictive hotspot neighborhoods.
- Master attention layer: Differentiates the contributions from static, local dynamic and global dynamic feature contributions.

Analysis of Features

Population	0.304
Gender (male ratio)	0.459
White alone	0.213
Black or African Am. alone	0.166
Am. Ind. or Alaska Nat.	0.001
Asian alone	1.354
Nat. Haw. and Other Pac. Isl. alone	0
Two or More Races	0.226
Hispanic	1.019
Median Household Income	0.423
Per Capita Income	0.403
Poverty	0.609

Static feature weights

No_Unique_Incidents	0.384
No_Incidents_UCR_Groups	0.279
Part_2_Minor	0.561
Theft	0.484
Burglary/Breaking Entering	0.450
Robbery	0.144
Aggravated Assaults	0.080
Rape	0.085
Unauthorized Use	0.099

Local dynamic feature weights

Our findings are consistent with the literature:
- A lack of economic resources may create communities with greater vulnerability to substance use.
- Communities with a higher concentration of economic stressors (e.g., low median income) may be particularly vulnerable to abuse of opioids as a way to manage chronic stress and anxiety and mood disorders.
- Theories of the drugs - crime connection predict that certain kinds of offenses, such as shoplifting, theft, robbery, burglary and prostitution are more likely than others to be associated with drug use and they might be committed to raise funds to purchase drugs.

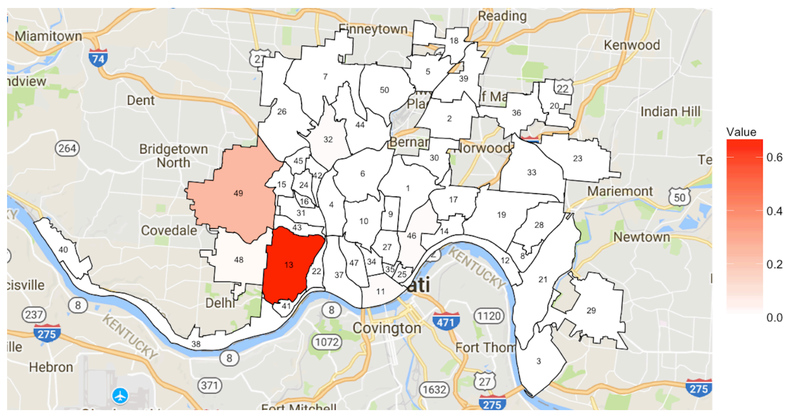
Evaluation

- Training: Data obtained for the first two years
- Validation: Data obtained for the next 3 months
- Test: Data obtained for the last 5 months

	RMSE	MAE	Pearson	Spearman's Rank
Baseline	2.954	2.003	0.701*	0.691*
Our model	**2.672**	**1.473**	**0.715***	**0.722***

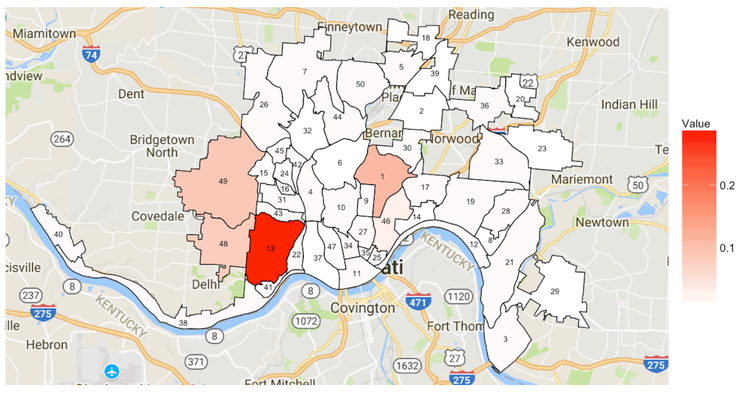
* $p < 0.001$

Predictive Hotspot Neighborhoods

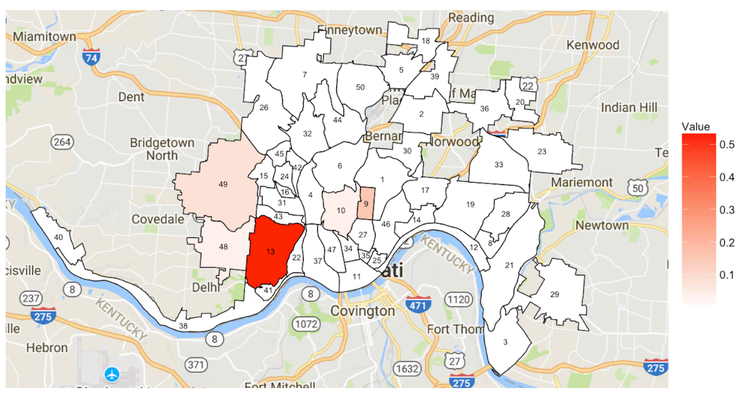


- The neighborhoods denoted with darker red color have more global contribution on forecasting heroin overdose occurrences on the other neighborhoods.
- The globally most contributing neighborhoods are:
  - East Price Hill (13)
  - Westwood (49)
- The neighborhoods with little contribution on forecasting are:
  - West Price Hill (48)
  - Walnut Hills (46)
- Remaining neighborhoods do not have contribution on forecasting overdose occurrences.

Change in Predictive Hotspot Neighborhoods



Aug 2015 – Dec 2016



Jan 2017 – May 2018

- The common predictive hotpots for both time intervals are:
  - East Price Hill (13)
  - Westwood (49)
  - West Price Hill (48)
- They are the neighborhoods where the number of crime incidents are the highest among all the neighborhoods
- Additional predictive hotspots before 2017 are:
  - Avondale (1)
  - Walnut Hills (46)

➢ The number of crime incidents in these neighborhoods decreases after 2017.

- Additional predictive hotspots after 2017 are:
  - Corryville (9)
  - CUF (10)

➢ The number of crime incidents in Corryville increases after 2017.