Forecasting and optimization of incidents for Austin Emergency Medical Services

Yangxinyu Xie[1], Joshua Ong[3], David Kulpanowski[2], Evdokia Nikolova[3], Ngoc Mai Tran[4]

[1]Department of Computer Science, University of Texas at Austin, , [2]Department of Emergency Medical Services, City of Austin, [3]Department of Electrical and Computer Engineering, University of Texas at Austin, [4]Department of Mathematics, University of Texas at Austin

Introduction

- The ongoing outbreak of the Covid-19 has caused overwhelming **disruptions** to healthcare systems around the globe, especially the emergency medical services (EMS).
- EMS models were developed **under normal conditions**.
- Unclear whether they can adapt to **large-scale disasters** such as the Covid-19 pandemic.
- Many EMS departments still make strategic decisions based on heuristics instead of data-driven solutions..

Research Goal

- examine the **long-term impact** of Covid19 on the temporal distribution of emergency calls.
- design a predictive model to **forecast the daily number** of Covid-19 pandemic EMS calls.
- optimize the stationing and routing problems using data-driven models.

Methods

Data

- ATCEMS database between January 2019 and December 2020
- For each incident, this dataset included its problem type, call disposition, priority number, and the date of the incident.

Statistical Methods

- Change-point detection to evaluate the impact of Covid-19 on non-pandemic incidents
- Student's t-tests for comparisons
- Time series regression to predict the daily frequency of pandemic EMS incidents

Optimization Methods

- Robust and stochastic linear programs to optimize ambulance stationing and routing.
- Discrete-time simulation to evaluate the efficacy of optimizations.

Figures and Results

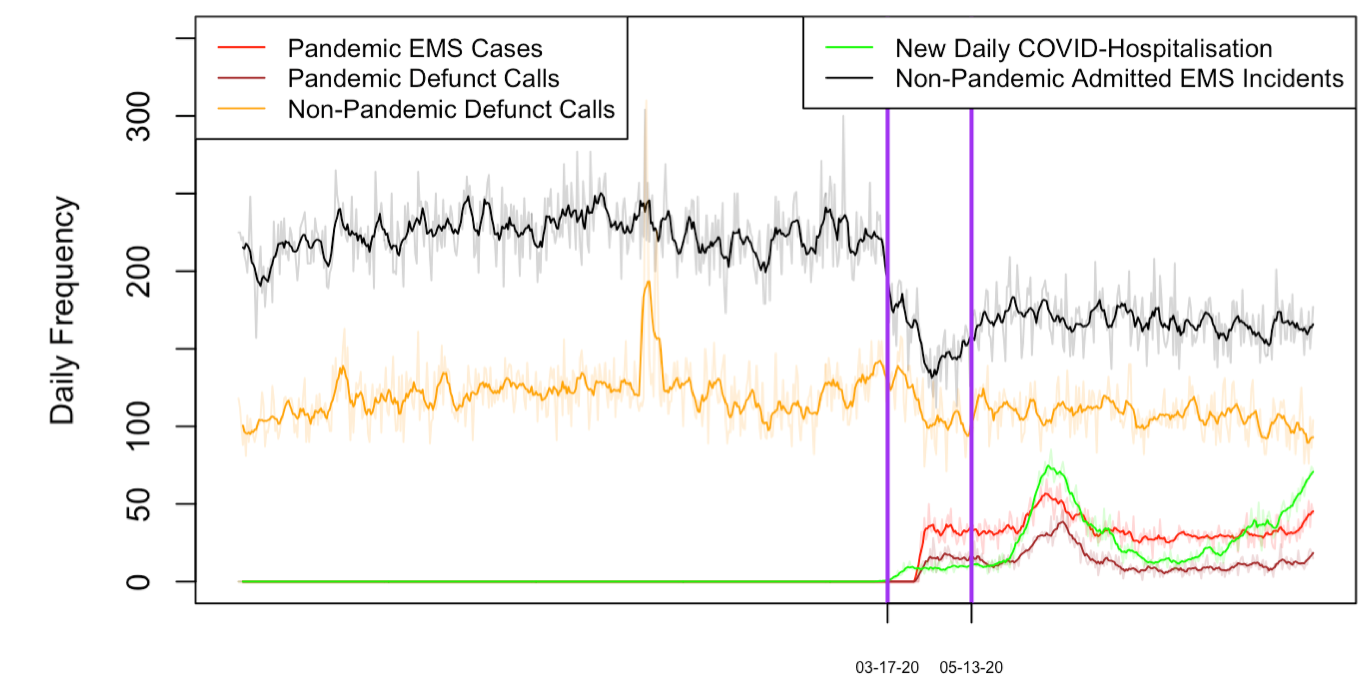
Overall Distribution

- **246,809** EMS incidents with ambulances dispatched
- **37** ambulances in Austin Travis County responded to **338** ± 34 calls per day

Impact of the Pandemic

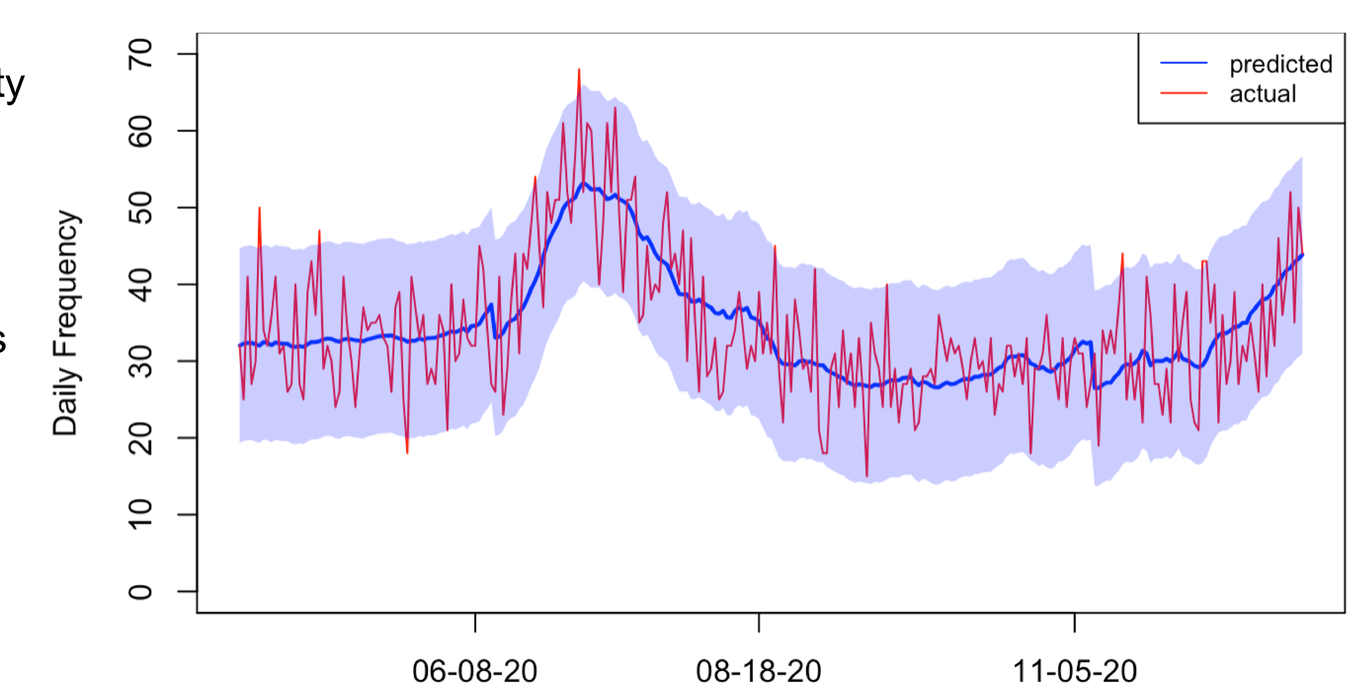
2 critical dates *mark changes in variance of the daily number of EMS incidents.*

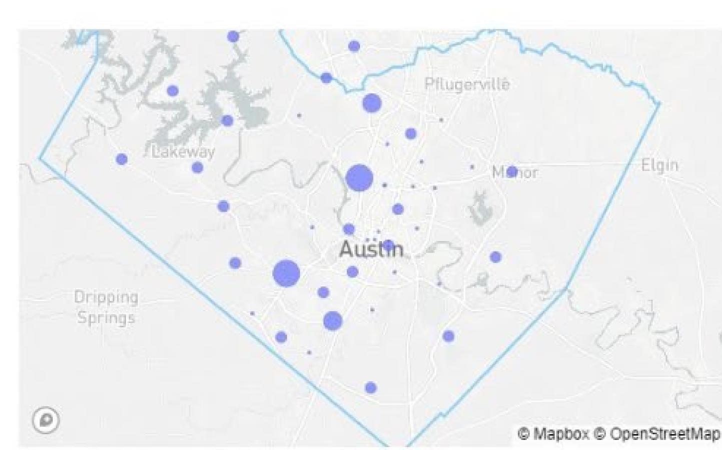
- **2020-03-15**: Austin shelter-in-place order. The daily number of EMS incidents **dropped significantly** and remained consistently lower in comparison to 2019.
- **2020-05-13:** the beginning of summer, by which the daily number of EMS calls climbed back to a new plateau, which is about **75% of that before March 17th**.

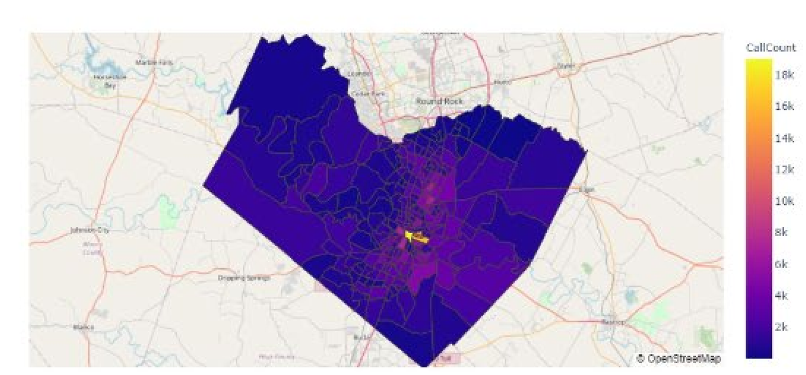


Covid-hospitalization predicts pandemic EMS calls

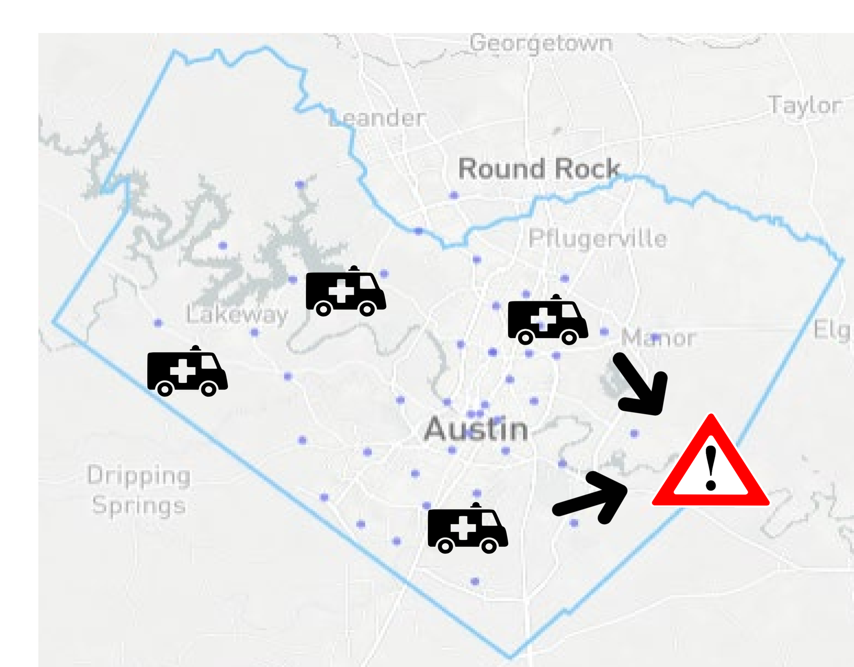
- The exact change point detection on variance with MBIC penalty yielded **4 Covid-19 hospitalization stages** since March 2020.
- The coefficients of the linear regression model shown in the Table.
- This model obtained an $\mathbf{r^2}$ value equal to **0.85**.
- Most of the actual daily frequencies of pandemic EMS incidents fall within the **95% prediction interval**.
- for every **2.5 cases** where EMS takes a Covid-19 patient to a hospital, **one person** is admitted.







On the left we see the optimal ambulance stationing. The number of ambulances stationed is represented as the magnitude of the circle (0-4). On the right we see the geo-spatial distribution of calls.



Simulation of Austin EMS

- 40 ambulances were stationed, which is the normal Austin EMS fleet size.
- Simulations were run on reported calls between the peak hours 8:00-20:00.
- Simulations were run on 1000 reported calls (around 2 weeks' worth of calls) and 12 batches in a multiple replication procedure (MRP).

Analyzing Optimization Results

- We observe that although there are many ambulance stations downtown, the model decides to place many stations in just a few of the locations around the perimeter of downtown. We hypothesize that this is because these locations are better because they can reach both downtown and the surrounding suburbs.
- On average, the optimal stationing improved the response time of ambulances by **88.02 ± 2.22** seconds.

Acknowledgments

This research is supported by the Good Systems Research Initiative, part of University of Texas at Austin Bridging Barriers. Ngoc Mai Tran is supported by NSF Grant DMS-2113468 and the NSF IFML 2019844 award to the University of Texas at Austin. Evdokia Nikolova is supported by NSF CCF 1733832. We would like to thank Prof. Junfeng Jiao for suggesting the CDC SVI data.
We thank Mauricio Tec for providing data on the hospital admission of Covid-19 patients in the Austin-Round Rock metropolitan statistical area.
We also thank Natasha Stewart for the insightful comments on earlier drafts.

References

- [Bertsimas, D. & Ng, Y. Robust and stochastic formulations for ambulance deployment and dispatch European Journal of Operational Research, 2019, 279, 557 - 571
- Tec, Mauricio, et al. "Austin COVID-19 transmission estimates and healthcare projections."
- All data sets were extracted from Austin Open Data Portal (https://data.austintexas.gov).
- The statistical analysis was performed using R statistical computing and graphics environment.
- The R code is available on GitHub(https://github.com/Xieyangxinyu/AustinEMS2020)