Predicting Emergency Medical Services (EMS) Call Volumes

NEMSIS
BETTER DATA. BETTER CARE.

Erdős Institute Data Science Bootcamp 2024

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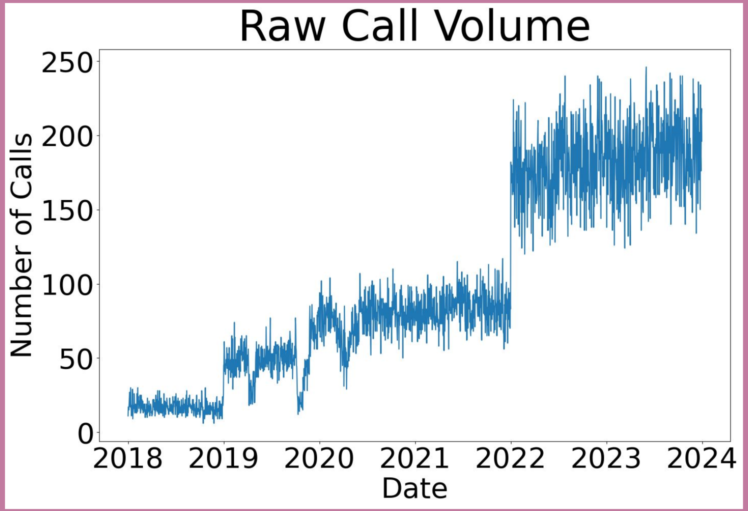
- **Emergency Medical Services [EMS]:** Public health service of paramount importance to stakeholders: our families; taxpayers; medical care personnel; local and state governments.
- **Challenge:** Allocation of scarce resources.
- **Data:** Rapidly expanding central national EMS event online database maintained by NEMSIS (https://nemsis.org/) with call time and category *anonymised* by state and county.
- **Aim:** Apply time-series methods to predict call volume for local call centers (agencies), so adequate resources can be deployed in advance.

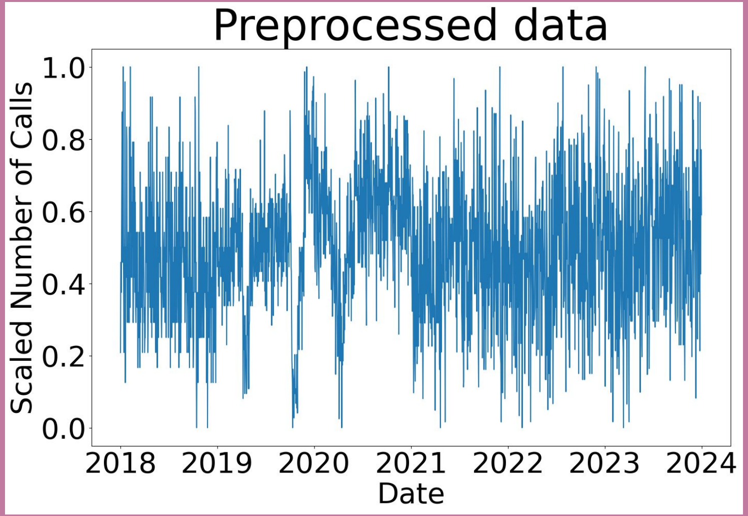
Data Engineering

- **Data from 2018-2023** graciously approved for our use by **NEMSIS**.
- **Anonymized** state and county event tables provided in **SAS format**.
- We (& GPT) **transformed data to SQL database** via sqlite3 together with bash and python wrappers to create .db files totalling ~1 TB
- External tables are **queried with sqlite3** and joined on location code and event type.

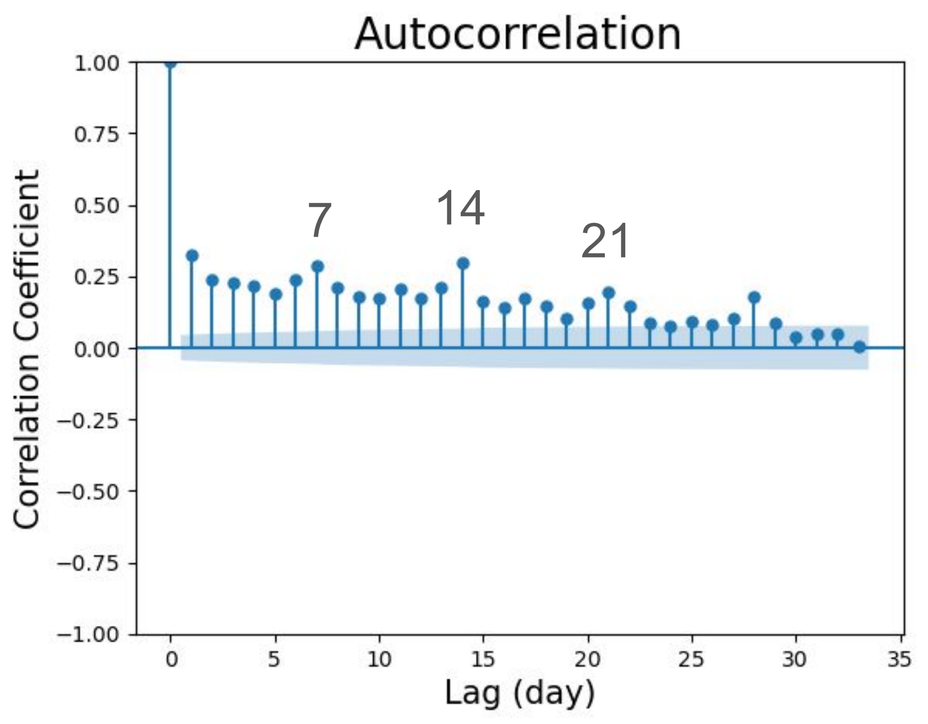
Preprocessing

- **We modeled call volumes** on the state or county level.
- Seasonality motivated us to try a **SARIMA model.**
- **Scaled each year of data** to create a stationary dataset and to **account for onboarding of new EMS agencies**.





SARIMA Model Selection



- Autocorrelation demonstrates **weekly seasonality**.
- Other SARIMA parameters were selected using the Akaike information criterion to **account for overfitting**.

State Space Models:

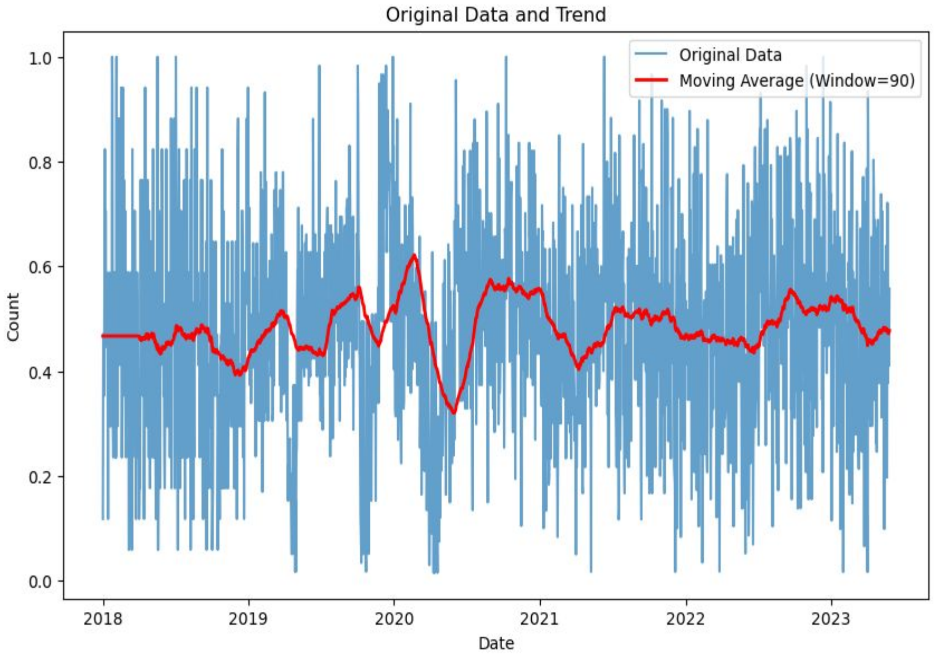
- **Exponential Smoothing**
  - Simple, interpretable, computationally efficient.
- **Facebook Prophet**
  - Complex, many parameters, models multiple scales of seasonality.
- **Facebook Prophet with lockdowns set as holidays**

Plot: exponential smoothing, Prophet, and naive model predictions

Combining the state-space models with SARIMA

Strategy:

- **Extract trend** with moving average
- **Compute detrended data**
- Predict each component separately:
    - **Apply a state-space model to trend component**
    - **Apply SARIMA to remainder component**



Hyperparameters:

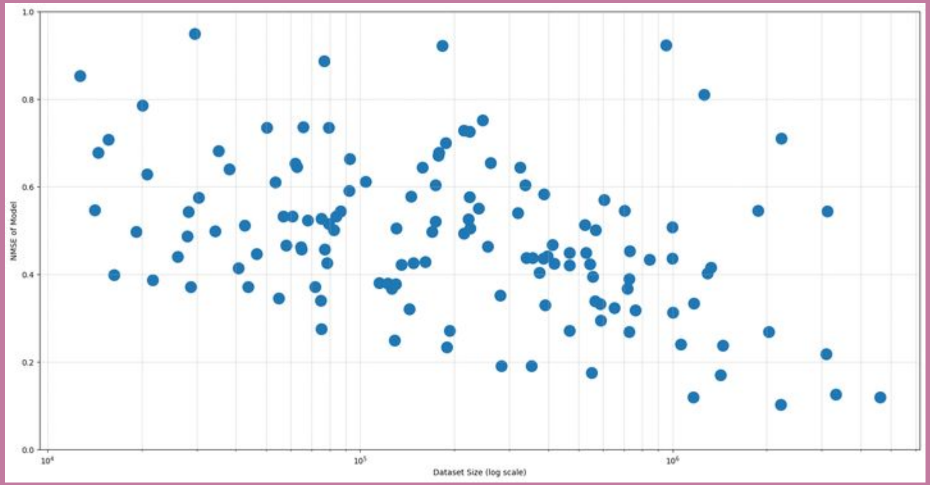
- **Window size** for the moving average
- **Type of decomposition into trend and detrended data**

Results on test counties:

Model with the **best average normalized mean square error (NMSE)** in testing was **Exponential-Smoothing + SARIMA**

Model with the next best average NMSE was **SARIMA**

(NMSE=MSE of model/MSE of naive model)



y=normalized mean square error (nmse) of exp-smoothing+arima
x=logarithm of dataset size

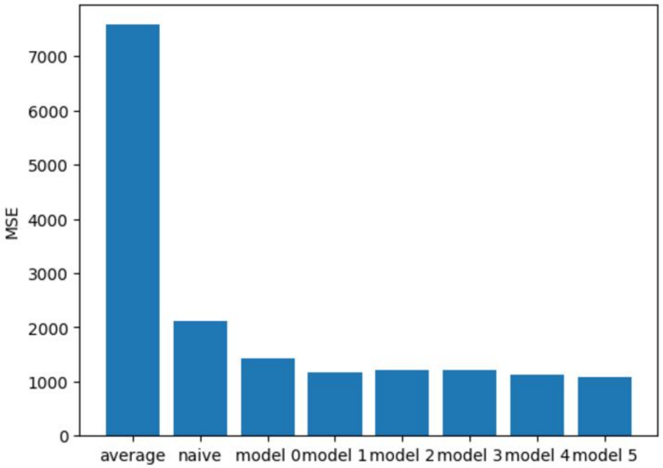
PFR55 (Dataset Size: 3,324,626)		
Model	MAE	NMSE
smoothing_arima_mult_120	333.955	0.7836
arima	363.000	0.9510
constant_predict	415.898	0.5651
naive_predict	488.711	1.0000
expsmoothing_predict	643.448	2.1422

Long Short Term Memory Networks (LSTMs)

	Date	2301071	2301061	2301033	everythingElse	Year
0	2018-01-01	1	5	8	13	2018
1	2018-01-02	4	3	0	17	2018
2	2018-01-03	2	5	4	17	2018
3	2018-01-04	3	5	6	20	2018
4	2018-01-05	1	3	4	20	2018
5	2018-01-06	1	2	5	13	2018
6	2018-01-07	0	3	3	14	2018
7	2018-01-08	2	6	1	21	2018
8	2018-01-09	0	7	4	12	2018
9	2018-01-10	1	12	3	10	2018

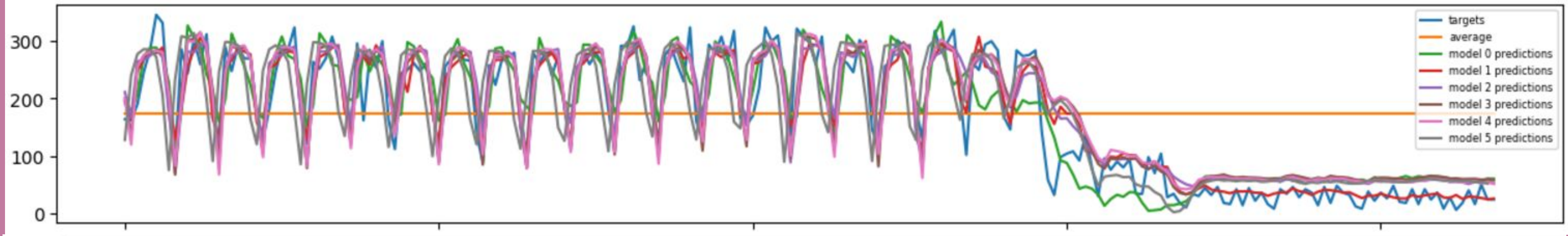
Input, eg. 6 day window

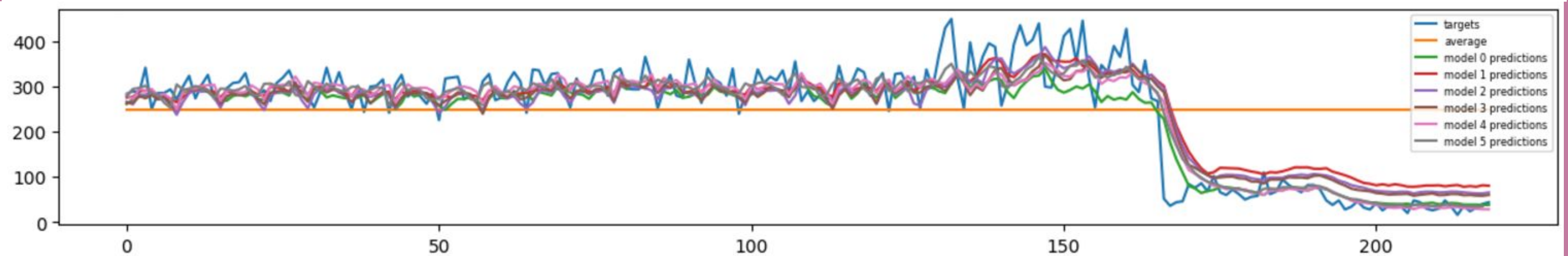
Target, the 7th day



County ERY72

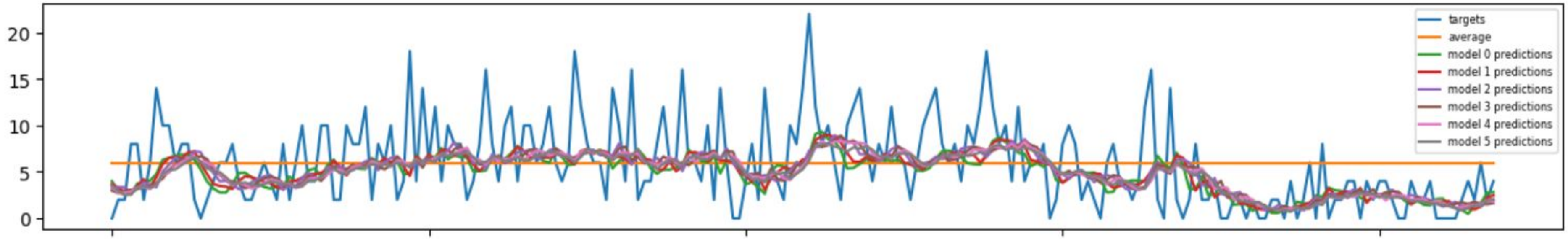
Most common call type and everything else



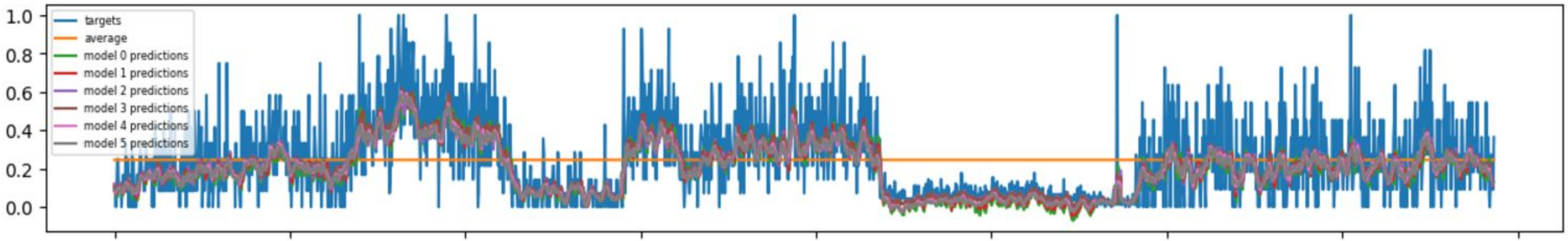


Data Collection, Size of County

Comparison of all models on a difficult county



Same comparison, but with all test years



How we helped:

- More accurate predictions of EMS call volume can help **optimize efficient scheduling of EMS personnel**.
- Data on model performance will **help stakeholders decide whether or not it is feasible to implement forecasting** in their jurisdiction.
- We recommend that EMS agencies make consistent data collection and reporting a priority to ensure accurate forecasting.


CBS EVENING NEWS

U.S. faces shortage of EMTs, nearly one-third quit in 2021

By Carter Evans, Simon Bouie
December 22, 2022 / 7:03 PM EST / CBS News