Source Detection Through Geophysical Data Fusion Methods

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Motivation

- Modernize geophysical sensing systems by enhancing traditional sensor networks with emerging smartphone sensors
- Utilize a smartphone sensor network for automatic event detection and localization
- Build a baseline model and be a starting point for developing a database with labeled data for machine learning comparison

Figure 1. Smartphone network locations surround SpaceX Florida launch site.

MTV Collaborators

- LLNL: Keehoon Kim, Jessie Gaylord and Steven Magana-Zook
- SNL: Daniel Bowman. Airborne platforms
- NNSS: Cleat Zeiler. LANL: Jim Smith. Source physics and processes
- INL: David Chichester. Pursue new signatures and methods

Mission Relevance

- This work contributes to nonproliferation efforts by modernizing geophysical sensing systems for acoustic source detection and characterization

Data

- Processed three SpaceX Falcon 9 launches, with each launch recorded by five smartphones
- Smartphone network near Cape Canaveral, FL
- Smartphone microphones record at 80, 800, 8000 Hz
- Smartphones also include barometer, magnetometer, accelerometer, and gyroscope
- Data segments were selected based on SpaceX launch times and acquired from https://redvox.io/reports

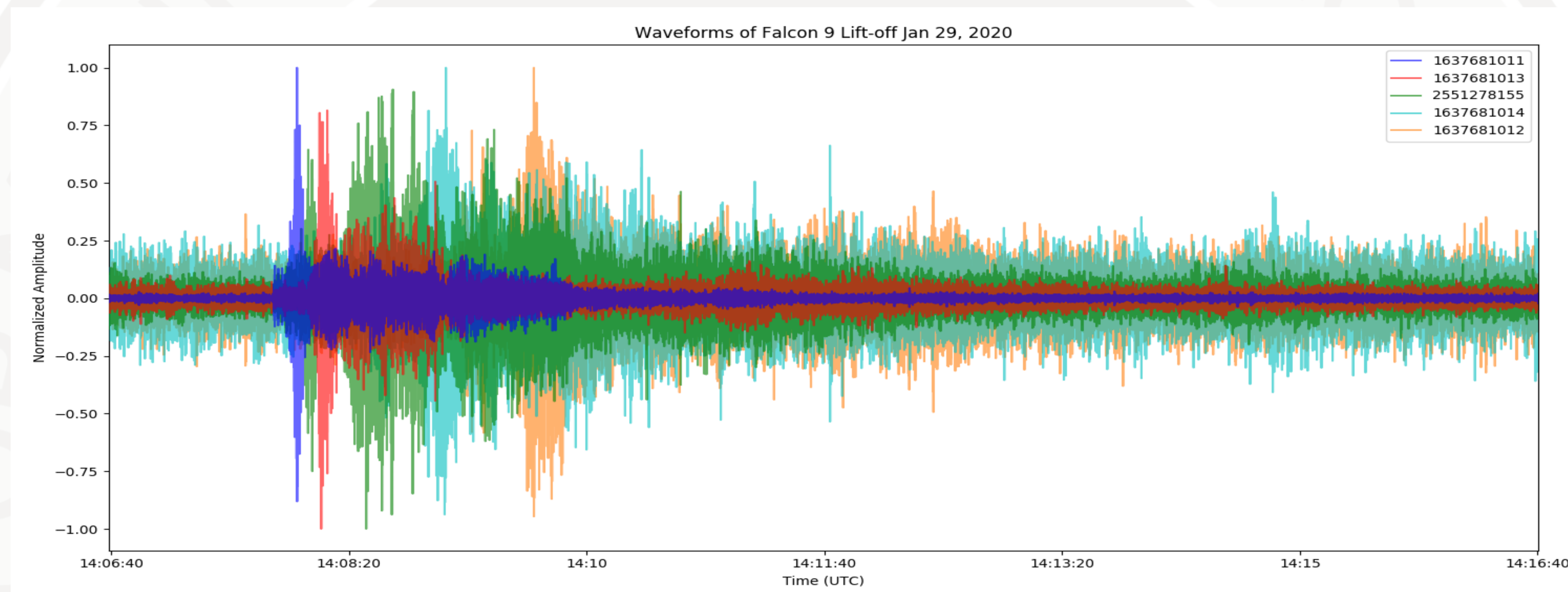

Figure 2. Waveforms of Falcon 9 launch from January 29, 2019 with amplitudes normalized to signal max values.

Methods

- Implemented standardized multiresolution threshold detection on acoustic data to acquire time difference of arrivals (TDOAs) between sensors
- Signal onset is determined by iterating through an SNR spectrogram of each frequency band below 40 Hz
- Initially all values less than the mean plus two standard deviations are set to zero, and the times of the first five nonzero values are acquired
- Times are compared to neighboring times to obtain a likelihood using percent difference
- The median in all the multiresolution bands of the most likely time is used as the onset time
- Used TDOAs to find the differences in distance from the unknown source between each sensor

$$\Delta d_{ij} = \Delta t_{ij} * c$$

- Converted GPS locations to earth centered, earth fixed (ECEF) coordinates and used a nonlinear least squares approach to estimate event location

$$d_i = \sqrt{(x_i - X)^2 + (y_i - Y)^2 + (z_i - Z)^2} - d_0$$

d0 = anchor sensor distance from source
X, Y, Z = source cartesian coordinates
di = sensor distance from source
x_i, y_i, z_i = sensor cartesian coordinates

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Results

- Source estimations for three Falcon 9 launches

Table 1. Results of model, comparing estimated result with real source.

Est Source (Lat, Long)	Real Source (Lat, Long)	Difference (km)
(28.55253, -80.61308)	(28.562106, -80.57718)	3.670
(28.52782, -80.62355)	(28.562106, -80.57718)	5.918
(28.53633, -80.60706)	(28.608389, -80.604333)	7.991

Conclusion

- SpaceX launch data recorded on smartphone network allows for in-depth analysis of event acoustics
- We were able to use this data for validation testing of our baseline model for automatic signal onset detection and localization

Next Steps

- Reduce error in time differences and compute 3D error ellipses
- Analysis of moving acoustic sources with stationary smartphone sensor network
- Trajectory tracking using band-limited TDOA with rolling correlation of acoustic signals
- Design methods for event detection and classification, including machine learning techniques

National Nuclear Security Administration