MATERIALS DATA SCIENCE RELY

MDS-Rely Center

www.mds-rely.org

Led by CWRU, PITT, & CMU

An NSF Industry/University Cooperative Research Center

(Award # 2052776 / 2052662)

RESEARCH PROJECT

A Data-driven Early Warning for Battery Thermal Runaway

Heqiao Ruan*,1, Shubha Sankar Banerjee*,1, Paul Leu[2], Satish Iyengar[1]

Department of Statistics[1], Department of Industrial Engineering[2], University of Pittsburgh

April 8, 2025

Project & Data Description

- We aim to develop data-driven methods useful for real-time detection of thermal runaway event in lithium-ion batteries subjected to external stressors and shocks.
- We adapt a slope-based procedure for change point (abrupt shift) detection[1] to the online update procedure.
- We extend the procedure to multiple-dimensional time-series via PCA on running windows.
- We have obtained data from companies[2] and university labs[3] to aid the research and test our methodology.
- Our method demonstrates strong robustness and efficiency in both real data and simulations.

Methodology

Slope-Based Abrupt Shift Detection Algorithm

1. Input: Univariate Time Series $T_s = (X_1, \dots, X_s)$.

2. For Window Sizes $w_{len} = w_l, w_{l+1}, \dots, w_u$:

a. Segment series into windows of length w_{len}.

b. Compute the slope in each window.

3. Detection:

a. If a slope exceeds the global mean by 3×MAD, mark the window as significant.

b. An observation's detection score = proportion of times it appears in significant windows.

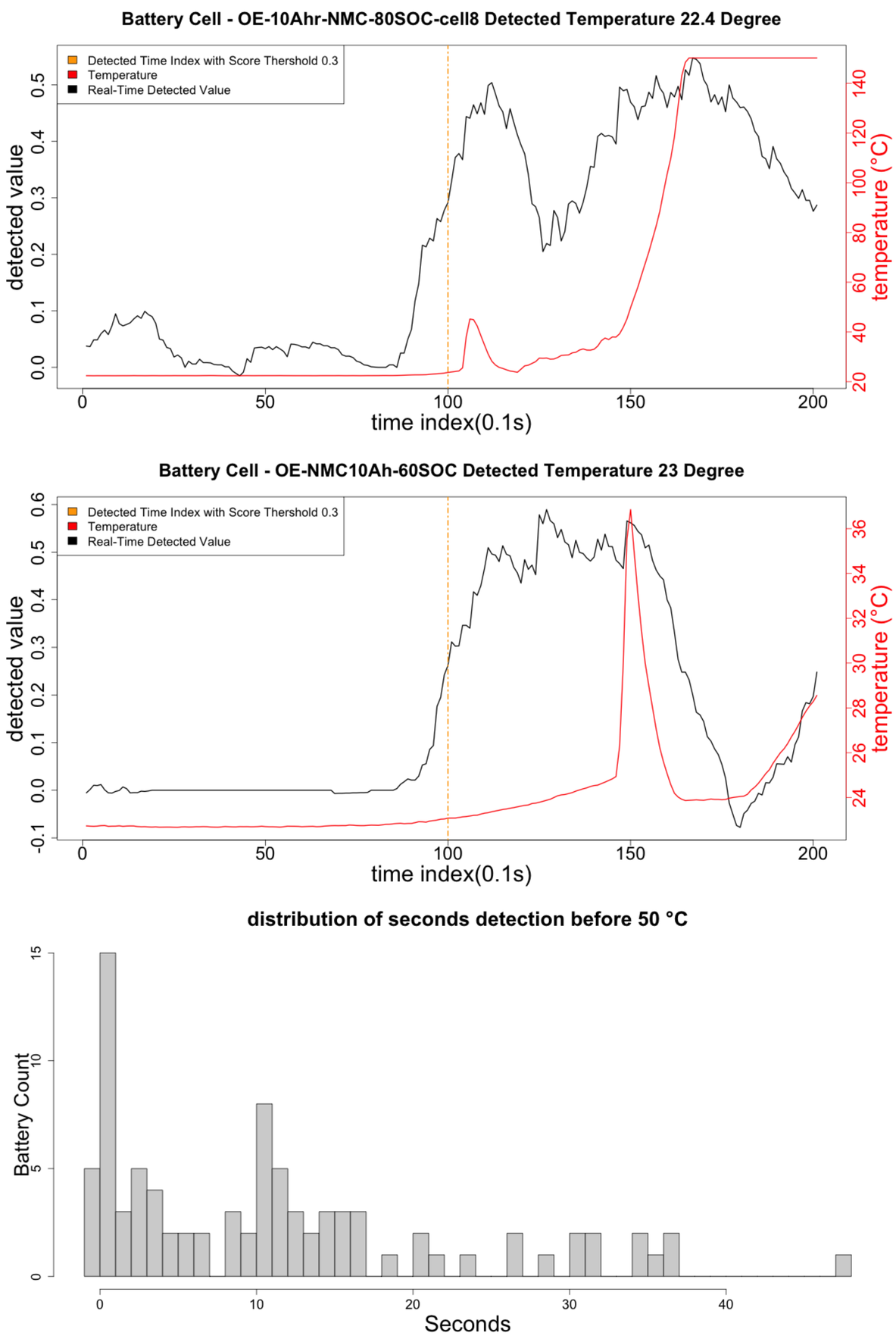
4. Real-time update:

Update the latest slope and detection score as new data arrives.

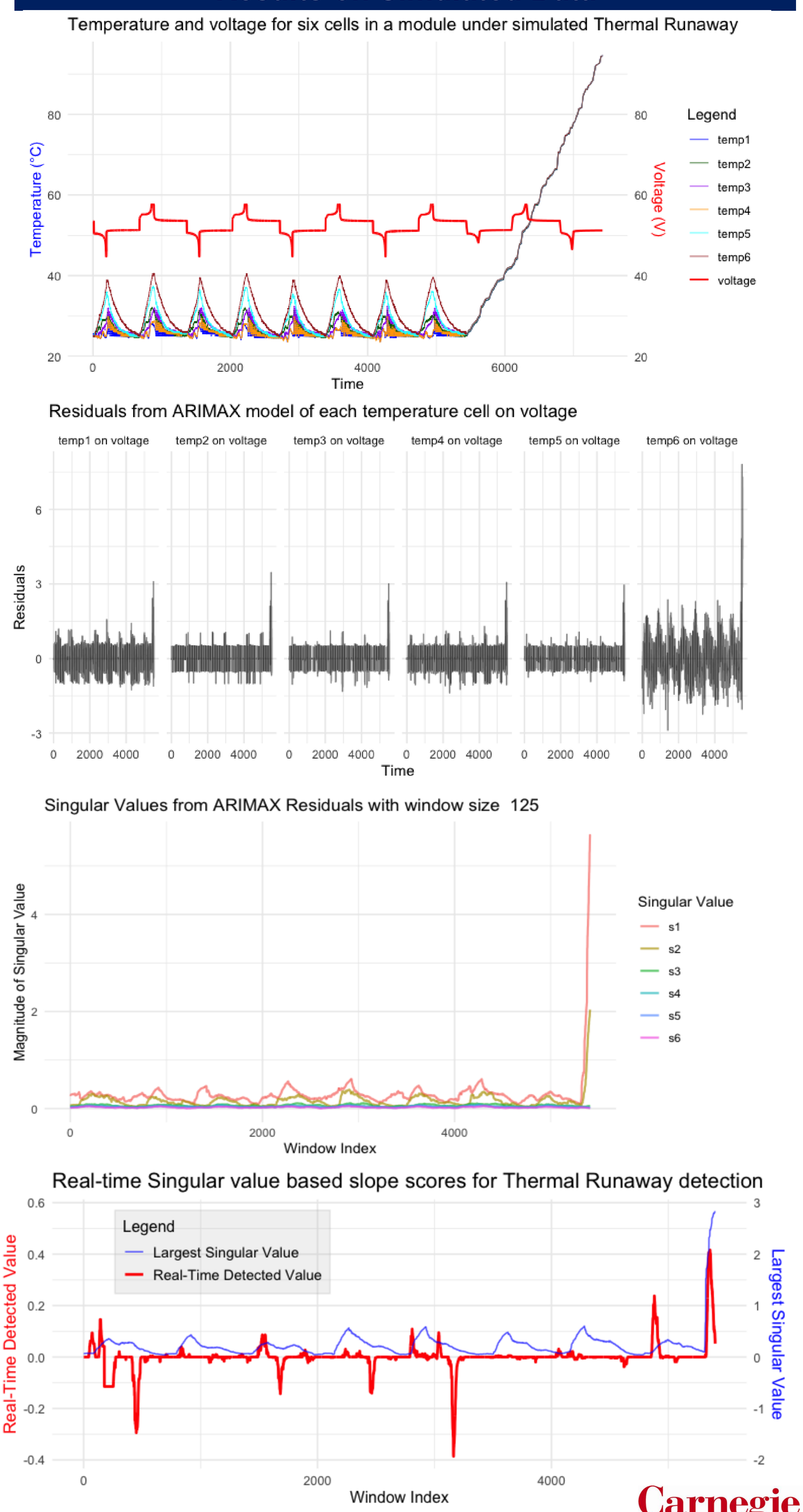
5. Multivariate Extension:

Apply ARIMAX to control dependence on other associated time series, apply PCA on the sliding window of the residuals; use leading singular value as an anomaly indicator.

Results for Real Data



Results on Simulated Data



References & Acknowledgement

We thank Mustapha Makki (Eaton) for insights and suggestions.

[1]Boulton et.al., "A new method for detecting abrupt shifts in time series", F1000Research, 2019.

[2]Eaton Corporation PLC.

[3]Lin et al., "Mechanically induced thermal runaway dataset on Li-ion batteries," Data in Brief, vol. 55, Art. no. 110609, 2024

CASE WESTERN RESERVE UNIVERSITY

PITT | SWANSON ENGINEERING

Carnegie Mellon University