Implementation of Anomaly Detection for the Next Generation Spacecraft Quick-Look System at ISAS/JAXA

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Source: JAXA

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1. About Me

- From Delft, The Netherlands
- Delft University of Technology
- 2nd Year MSc Aerospace Engineering student
- 6 Month internship in the Ebisawa Laboratory at ISAS/JAXA
- 2 Projects
  - *Development of a quick-look prototype system with anomaly detection*
  - X-ray black hole novae similarity research

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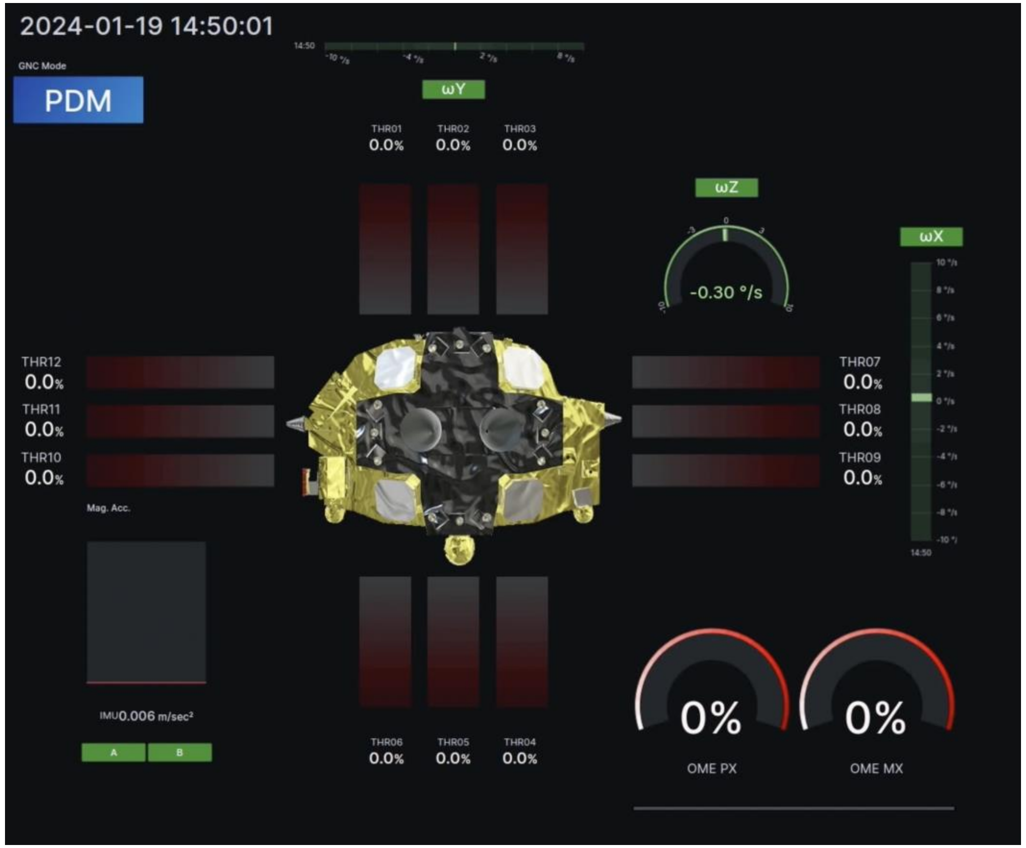
2.1. Problem Statement

Current State:

- SLIM quick-look system
- Limit checking

System extension:

- Active anomaly detection on all scales



Source: ISAS/JAXA

2.1. Problem Statement

“There is need for a quick-look system with active anomaly detection for the current and next-generation of satellites and spacecraft at ISAS/JAXA.”

2.2. Requirements

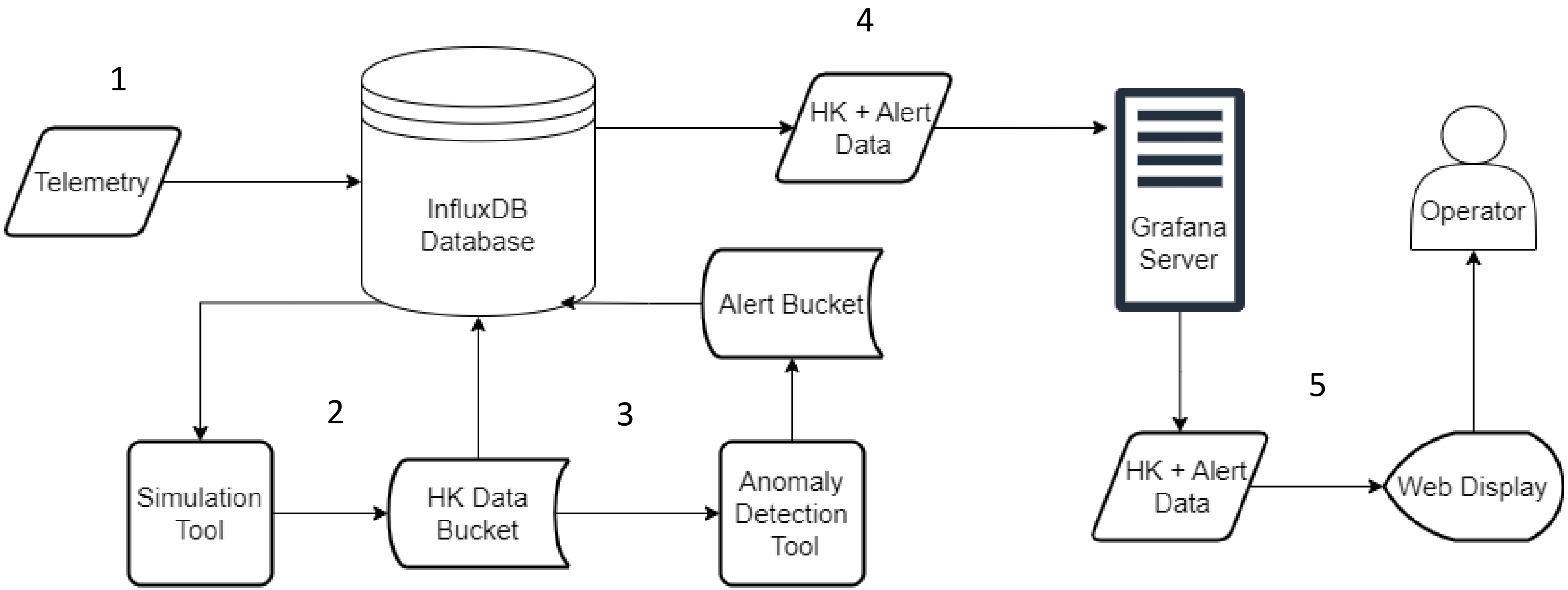
1. The system shall be applicable to any satellite or spacecraft
    1.1 The system shall be separate from the satellite or spacecraft
2. The system shall use an active anomaly detection subsystem
    2.1 The anomaly detection subsystem should be exchangeable
3. The system shall include an alert subsystem
    3.1 The response time of the alert subsystem should be $< 2s$
4. The system shall include a web-based monitoring option

2.3. System Outline

System fundamental components

- InfluxDB: a time series database
- Grafana: a web-based UI
- Python: a scientific programming language

2.3. System Outline



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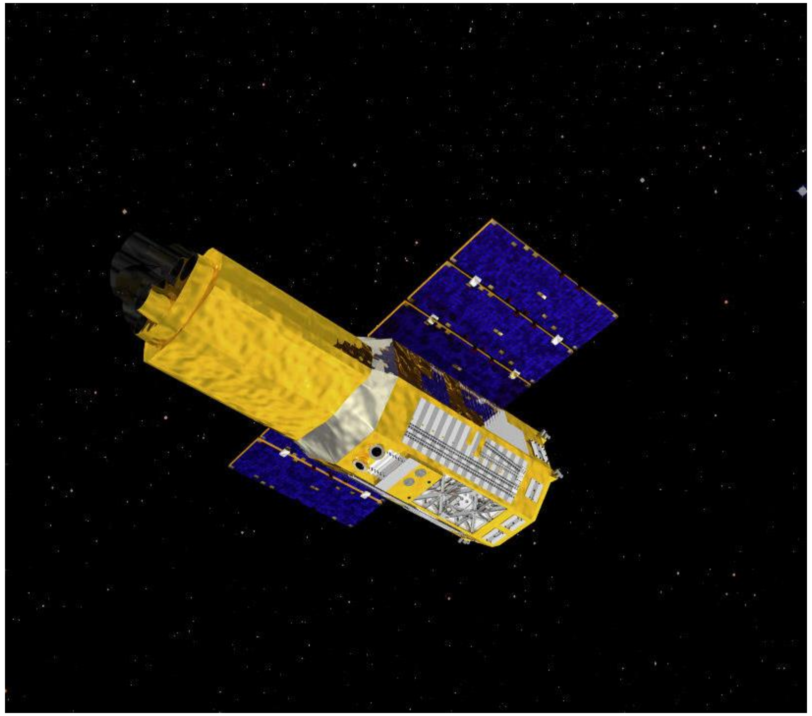
3.1. Sample Data Set

Suzaku X-ray astronomy satellite

- Launched July 10, 2005
- Suffered eventual battery failures [1]
- Battery HK data
  - 1d data available through DARTS [2]
  - 1s data obtained from Yoshitomo Maeda
  - Ideal for developing and testing of the quick-look prototype



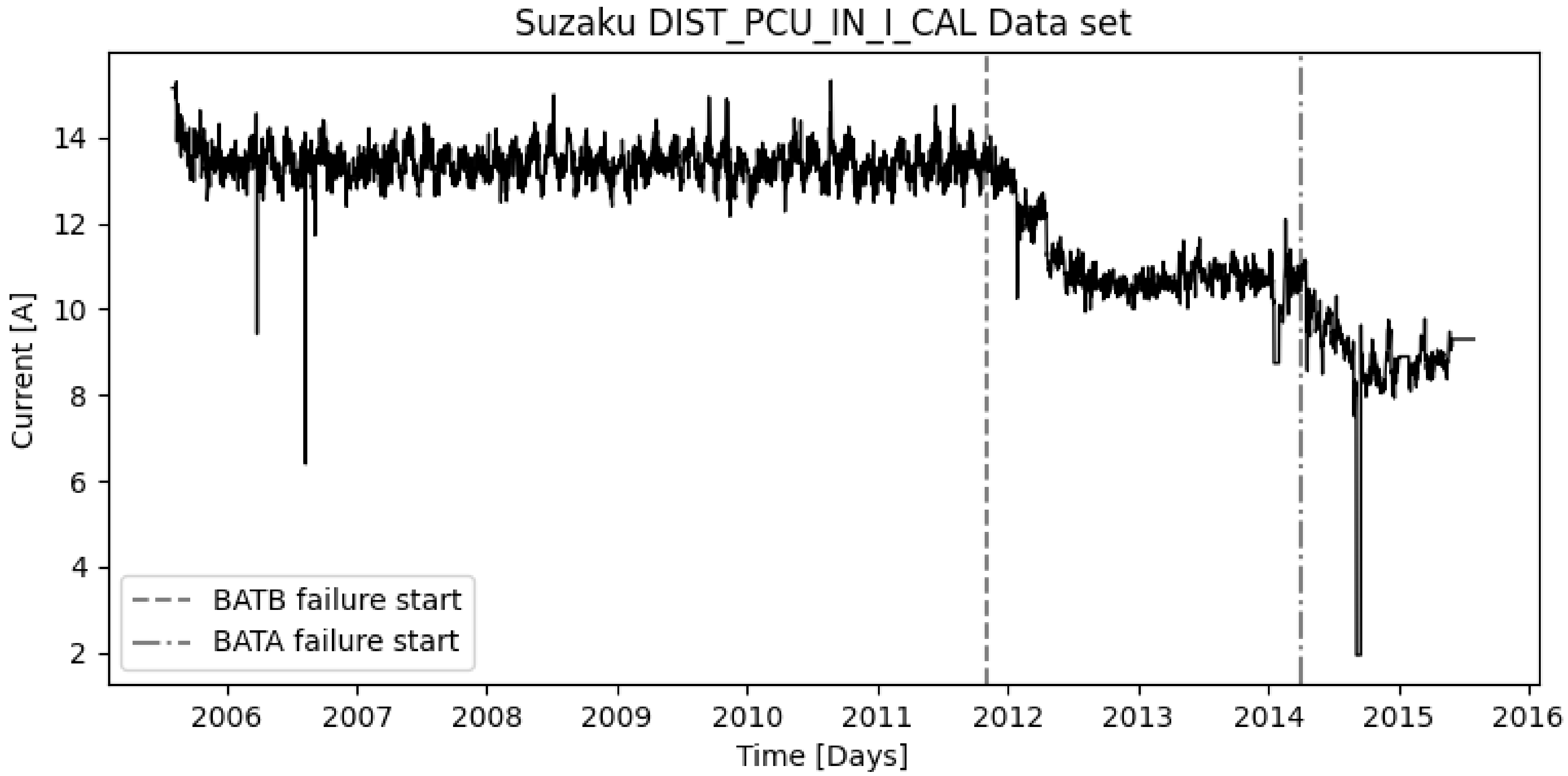
Source: JAXA/ISAS

[1] Y. Maeda, A story of the Operation of the Suzaku Battery and the Solar Array Paddle, The Astronomical Herald, 2016
[2] DARTS

3.1. Sample Data Set

Large time scale (1d) data analysis

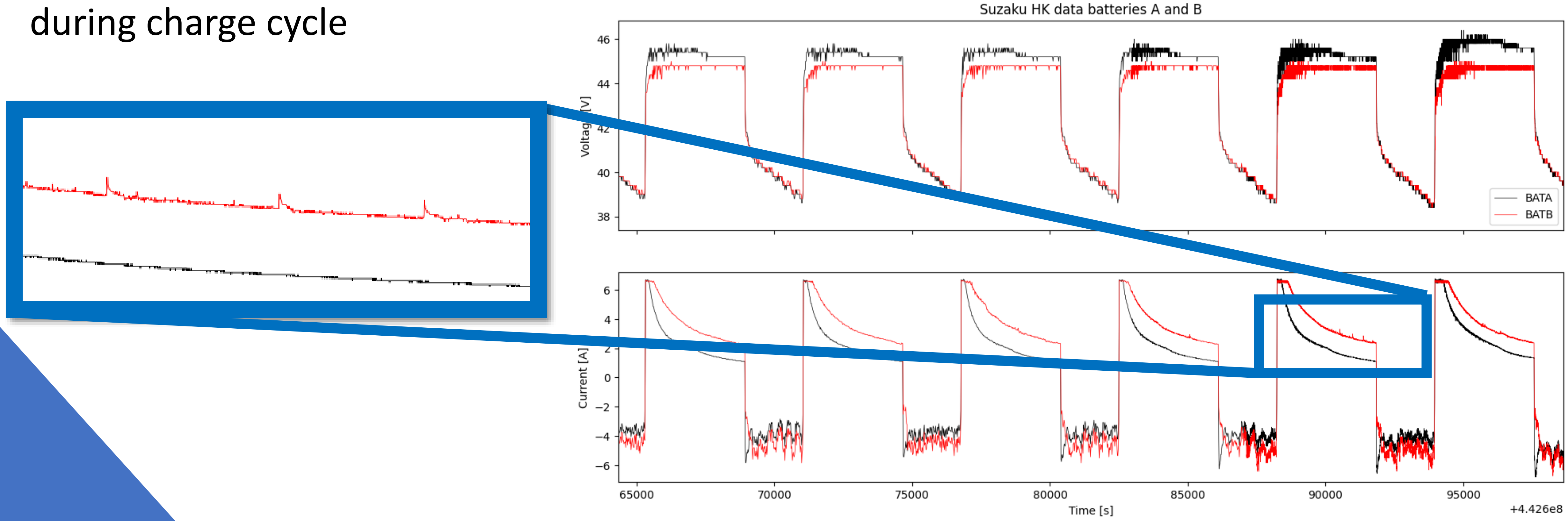
- Downward trends indicate battery failures



3.1. Sample Data Set

Small time scale (1s) data analysis

- Spikes occurring in BATB current during charge cycle



3.2. Methodologies

2 Anomaly detection approaches

- Large scale approach
  - Measure deviation from predicted data by the SARIMA algorithm
  - Well known time series forecasting algorithm
- Small scale approach
  - Direct detection of current spikes through custom algorithm
  - Based on statistical methods

3.2. Methodologies

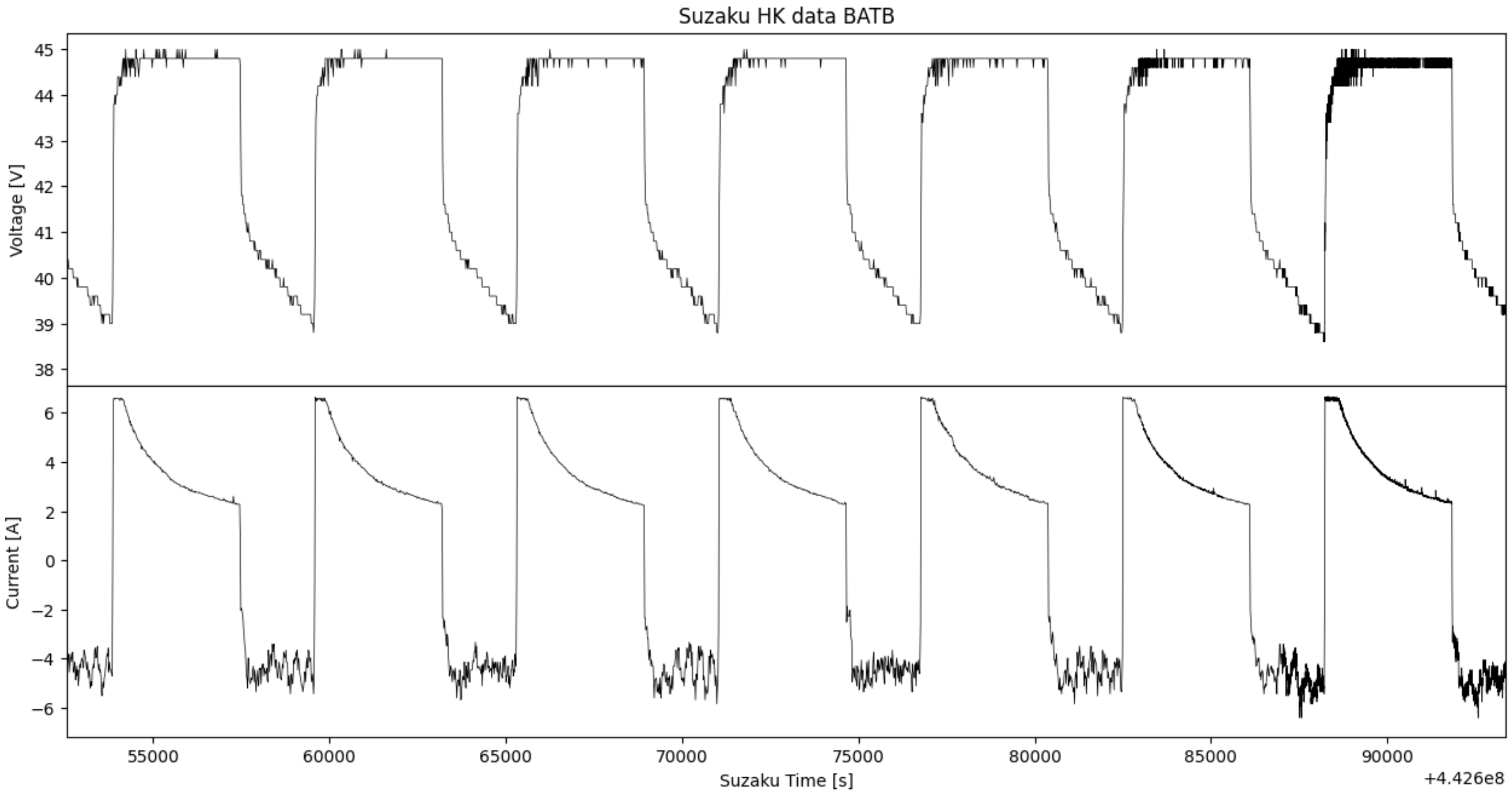
SARIMA algorithm

- Abbreviation for Seasonal Auto Regression Integration Moving Average
- Uses historical data as training input
- Includes 6 parameters
  - Parameter determination using (partial) autocorrelation functions and manual iteration
- Anomaly detection when $I_{observed} > I_{predicted} + k\sigma$ or $I_{observed} < I_{predicted} - k\sigma$

3.2. Methodologies

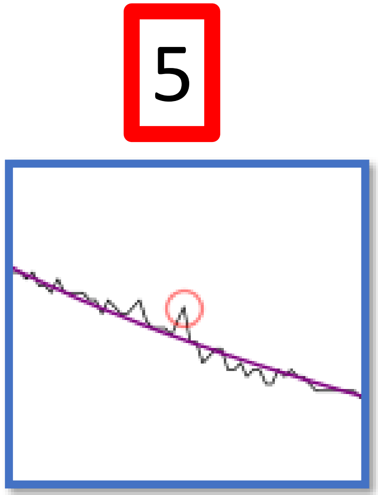
Spike detection algorithm

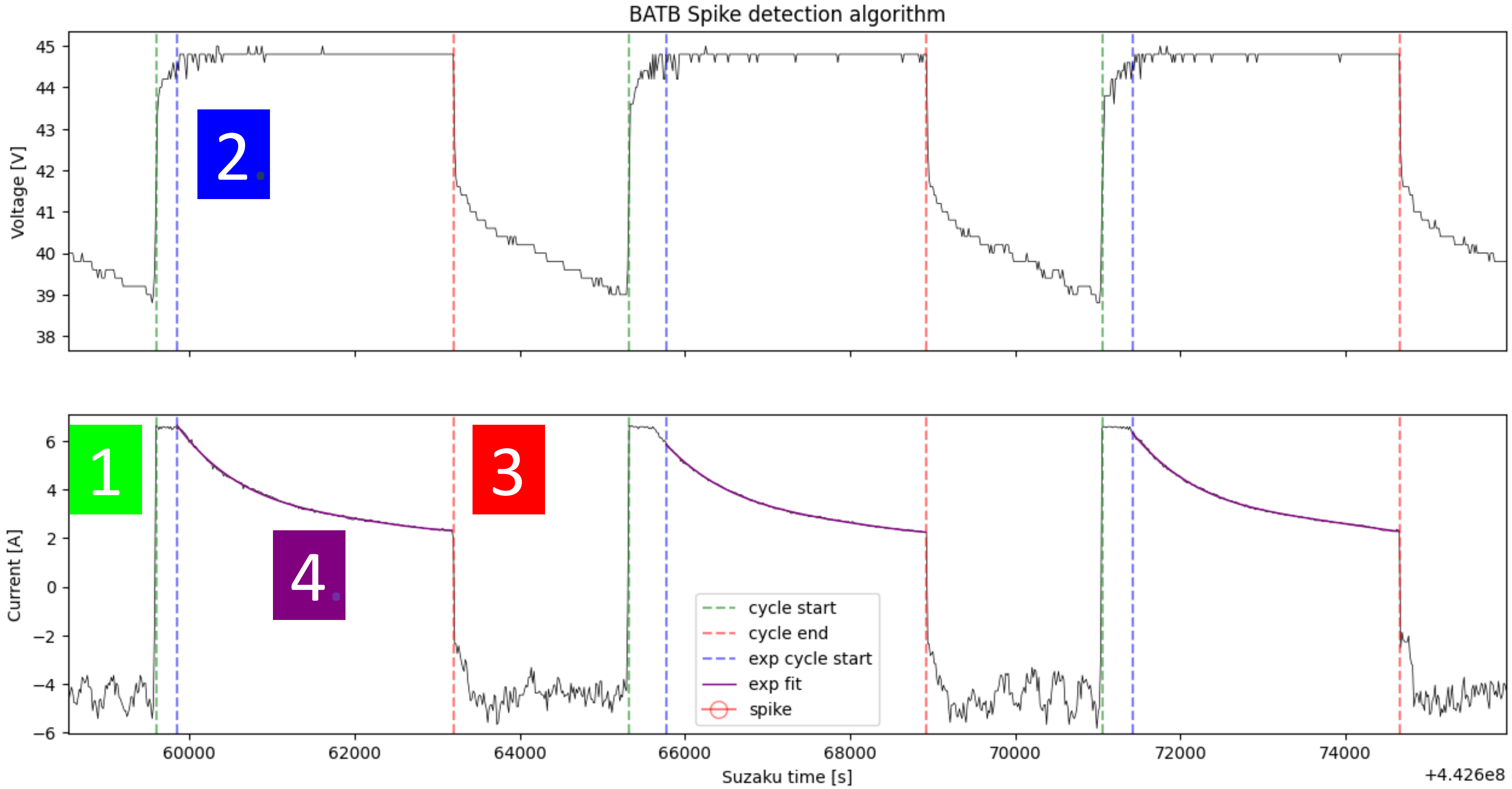
- Small scale HK data analysis
  - Charge cycle starts when $I > 0$ and ends when $I < 0$
  - Current spikes in exponential slope
  - Exponential current slope coincides with voltage becoming steady during charge



3.2. Methodologies

Spike detection algorithm





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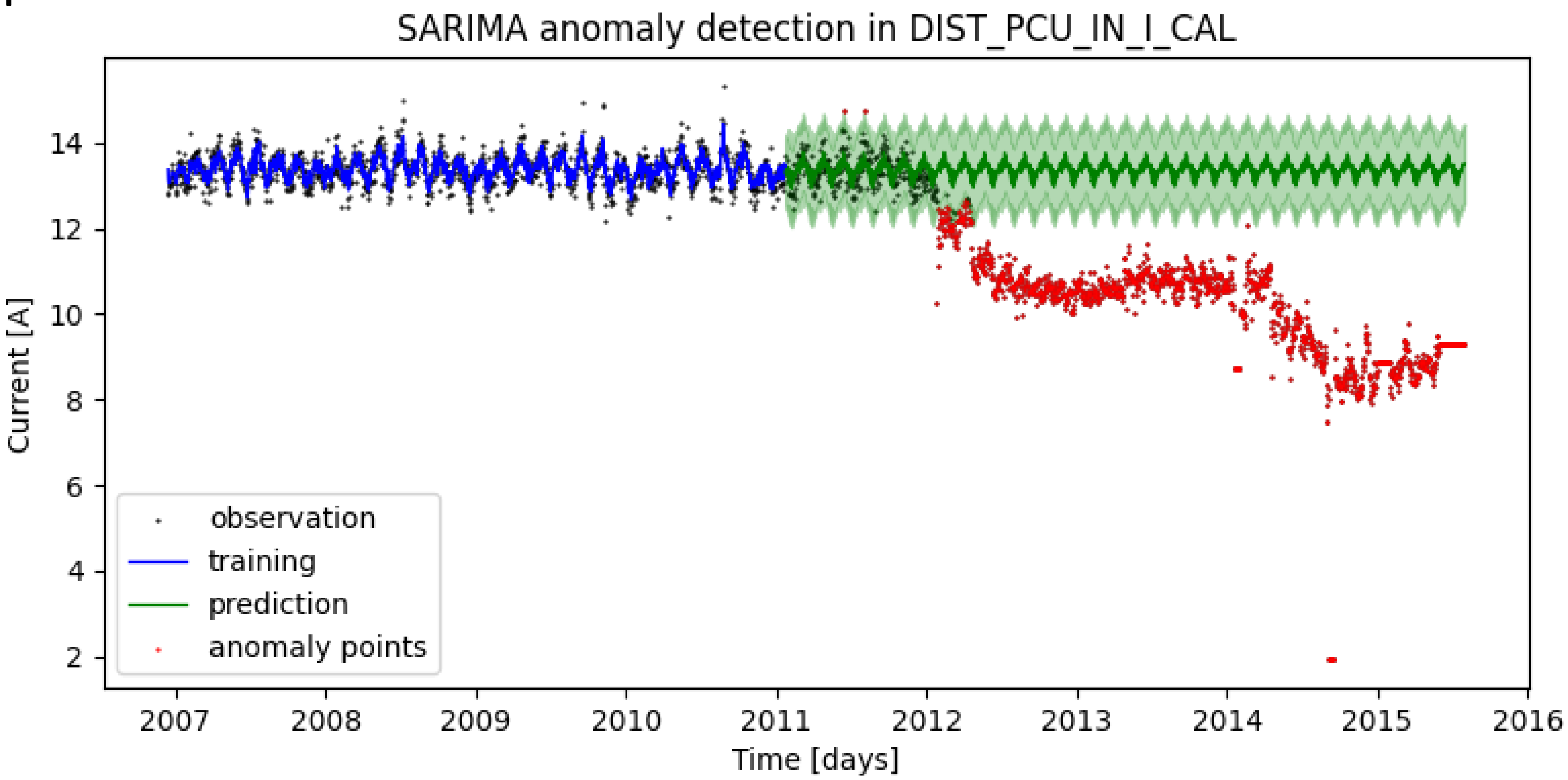
4.1. SARIMA

SARIMA Results

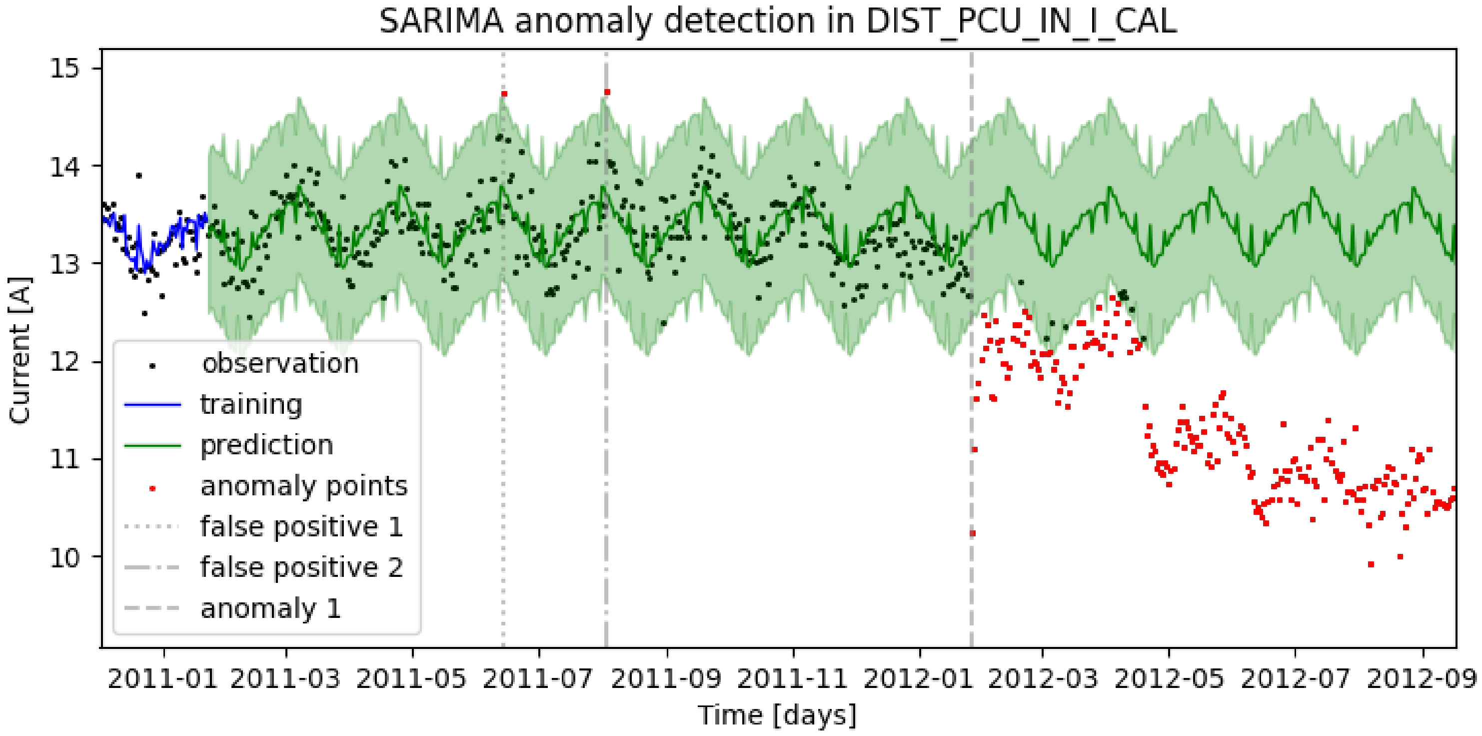
- Offline detection



4.1. SARIMA

SARIMA Discussion

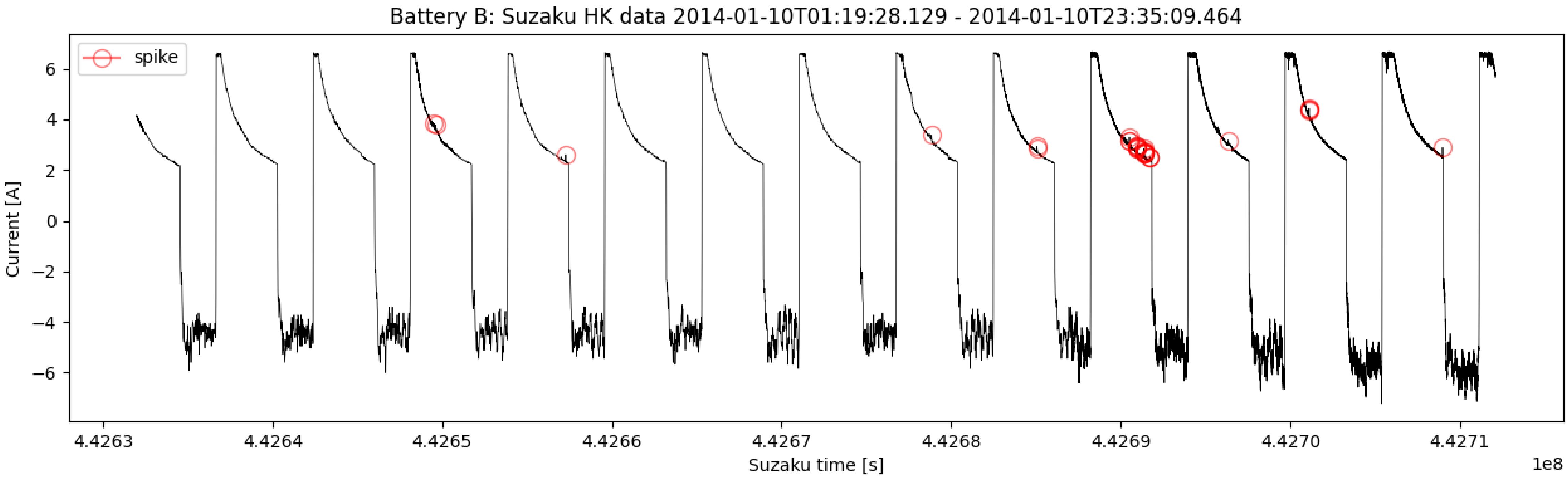
- First 2 detections false positives
- The 3rd detection actual anomaly
- Time intensive parameter selection
  - Automatic selection not successful
- Effective in detecting anomalies on large scale
- Option for implementation into quick-look prototype system



4.2. Spike Detection

Spike detection results

- Offline detection



4.2. Spike Detection

Spike detection discussion

- Easy parameter selection
  - 3 values > low complexity
  - Potential for automation
- Fast process time < 1s
- Detection efficiency: > 80%
- Suitable for implementation into quick-look prototype system

4.3. Implementation

Spike detection implementation

- Real time anomaly detection and data display
- Ability to share dashboard through permalink

https://{grafana}/query?&var-select=DIST_BATA_V_CAL&var-select=DIST_BATB_V_CAL&var-select=DIST_BATB_I_CAL&var-select=DIST_BATA_I_CAL&var-width=1d&from=1122385314127&to=1434430216749

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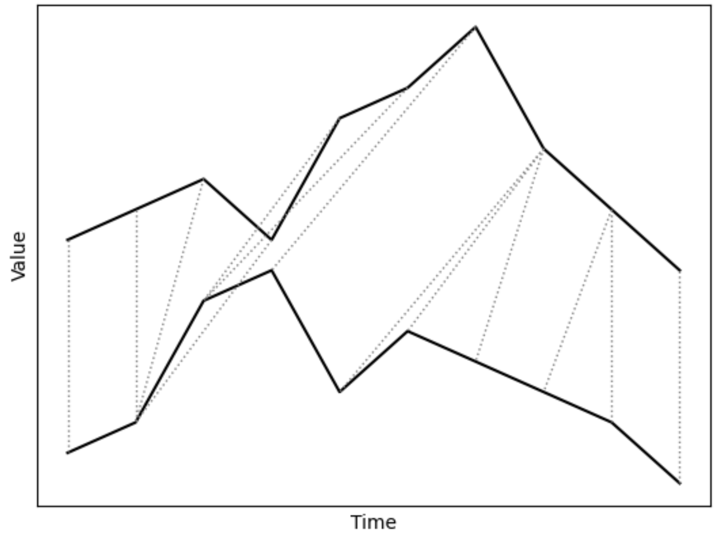
5.1. Summary

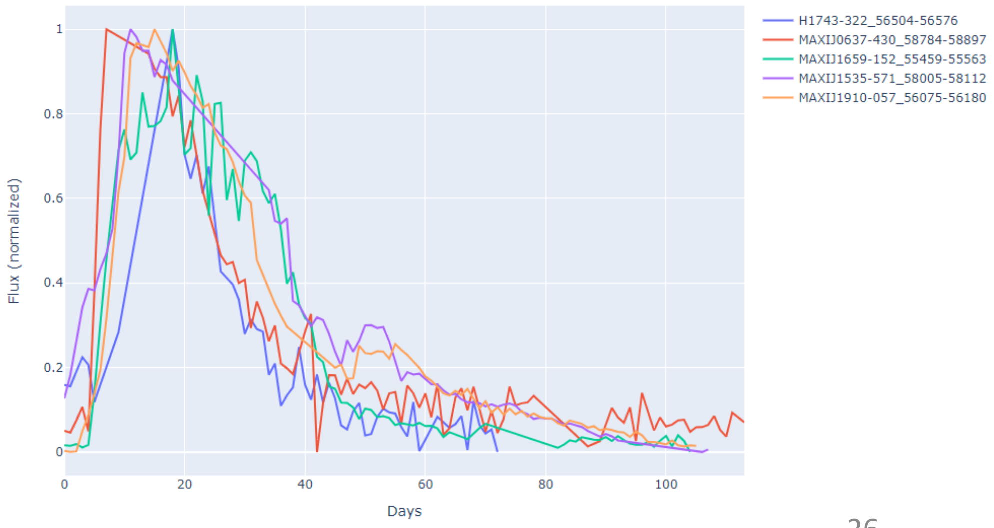
Successfully built a quick-look prototype system with active anomaly detection by:

- analysing Suzaku battery HK data
- deducting 2 approaches for anomaly detection
- developing and implementing a spike detection algorithm
- testing the complete system on Suzaku battery HK data

5.2. Recommendations

- Implement SARIMA to detect large scale anomalies
- Testing of the spike detection on more battery data sets
- Developing anomaly detection algorithms for components other than batteries
- Developing a generalized anomaly detection algorithm
  - Using for example template fitting & dynamic time warping





Thank you for your attention

Are there any questions?