Lockloss Prediction

Rutuja Gurav, UC Riverside

Prediction Stage

Use recorded data streams to build a model that can predict a lockloss ahead of time.

Challenges:

1. Extract **relevant features** from **a set of channels**.
2. Choose the appropriate **SEGMENT LENGTH** and **SEGMENT BUFFER** before event for each channel.

Diagnostics Stage

Use the trained model to find lockloss witnesses

Challenges:

1. **Down-select** a set of channels having features strongly correlated with a lockloss event.
2. **Follow-up** on corresponding channels.

Intervention stage

Traditional route:

Transition to earthquake mode? (takes 60-260 seconds)

ML route:

Reconstruct motion of mirrors for lock acquisition.

Challenges:

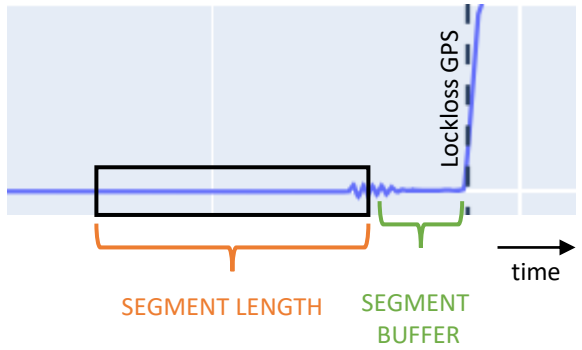
Traditional route:

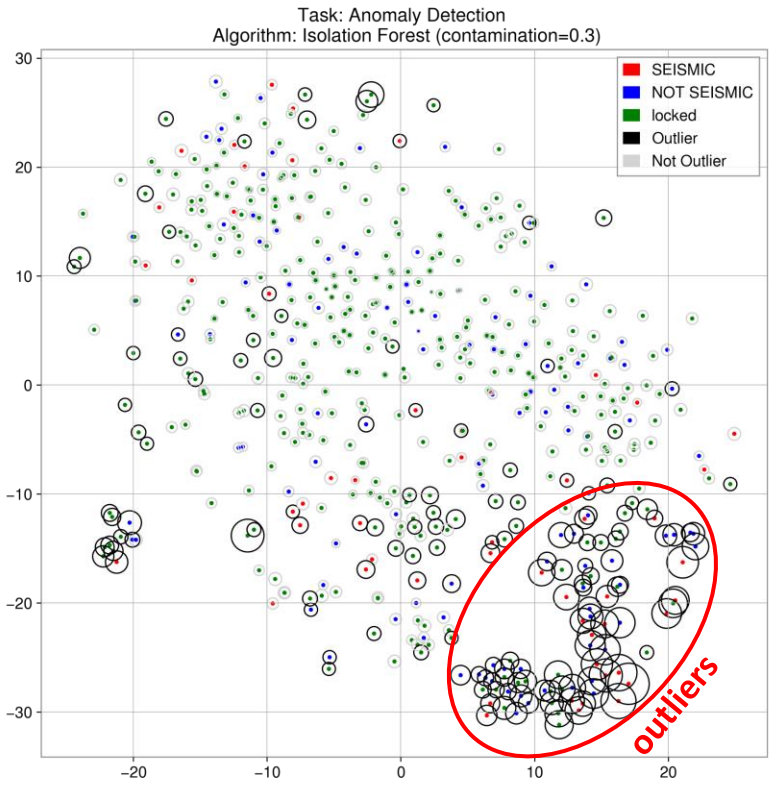
How close to the actual lockloss event is an early warning effective?

ML route:

Status of RNN-based TM motion reconstruction unknow.

Dataset Creation





2-D projection of 276-D data using t-SNE (for visualization only)

Channels: 23 Length and Angular DoF channels

Features:

12 summary statistics*23 channels = 276 features

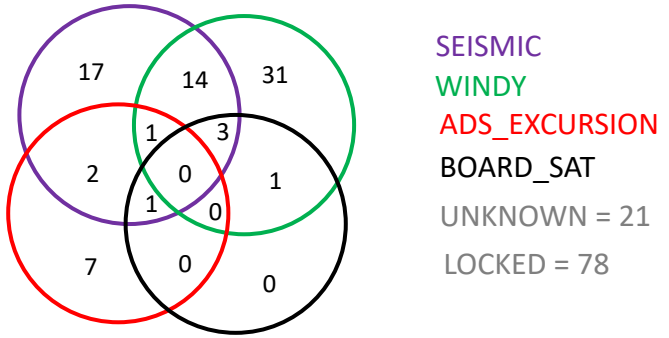
{energy, difference, complexity, mean, standard deviation, variance, kurtosis, skewness, sample entropy, approximate entropy, absolute sum of changes, mean absolute change}

Hanford O3a : 169 (lockloss) + 364 (locked) samples

Lockloss tags	Count
SEISMIC	56
BOARD_SAT	10
WINDY	41
ADS_EXCURSION	32
BRS_GLITCH	2

Results:

160 samples predicted as outliers



None of the BRS_GLITCH related locklosses predicted as outliers using **100 second segments 300 seconds away** from locklosses using Length and Angular DoF channels (mean, s-trend).

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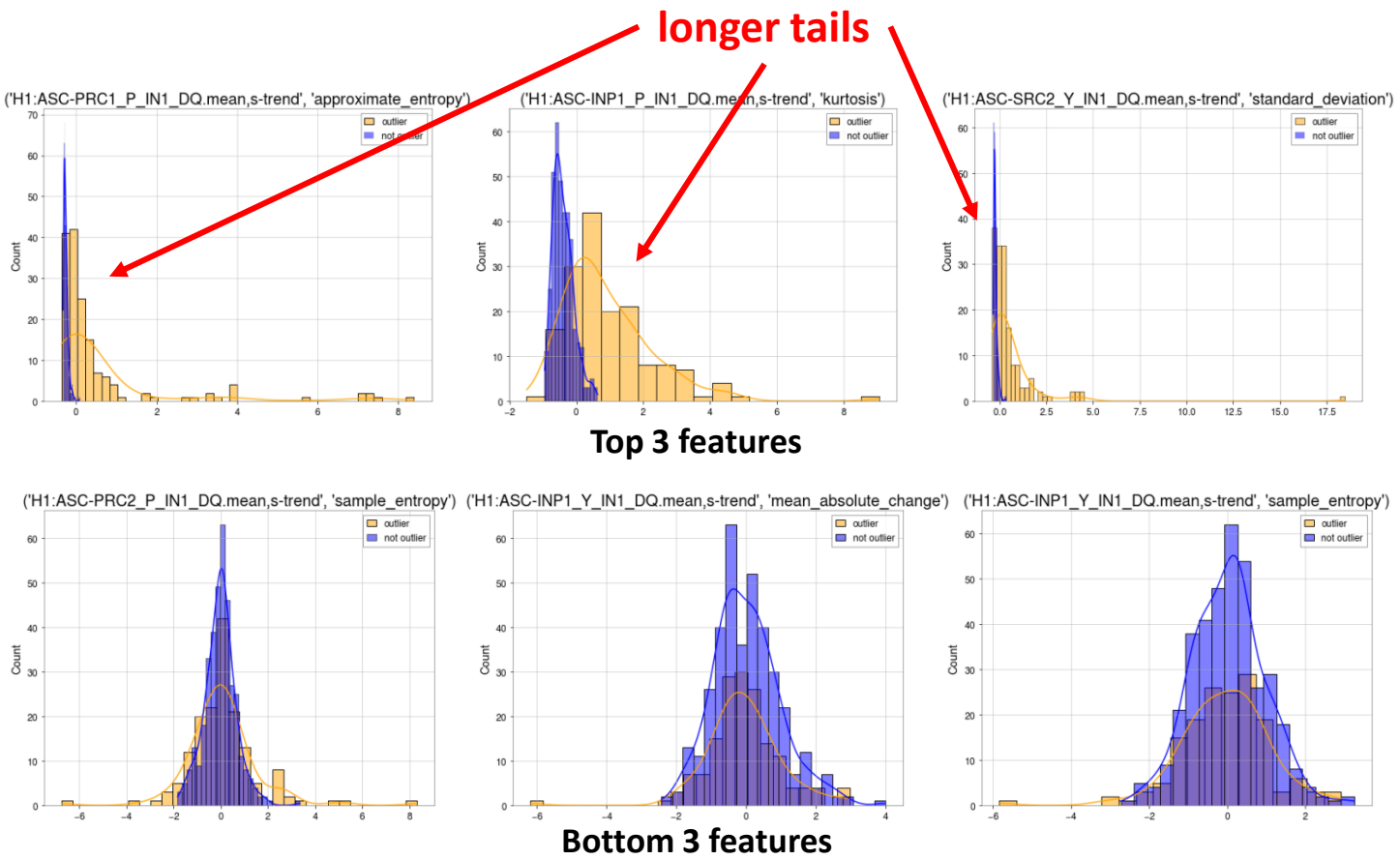
Determine important channels using a surrogate model

For Surrogate modelling –

Task: Binary Classification
Classifier: Random Forest
Targets: Isolation Forest predictions



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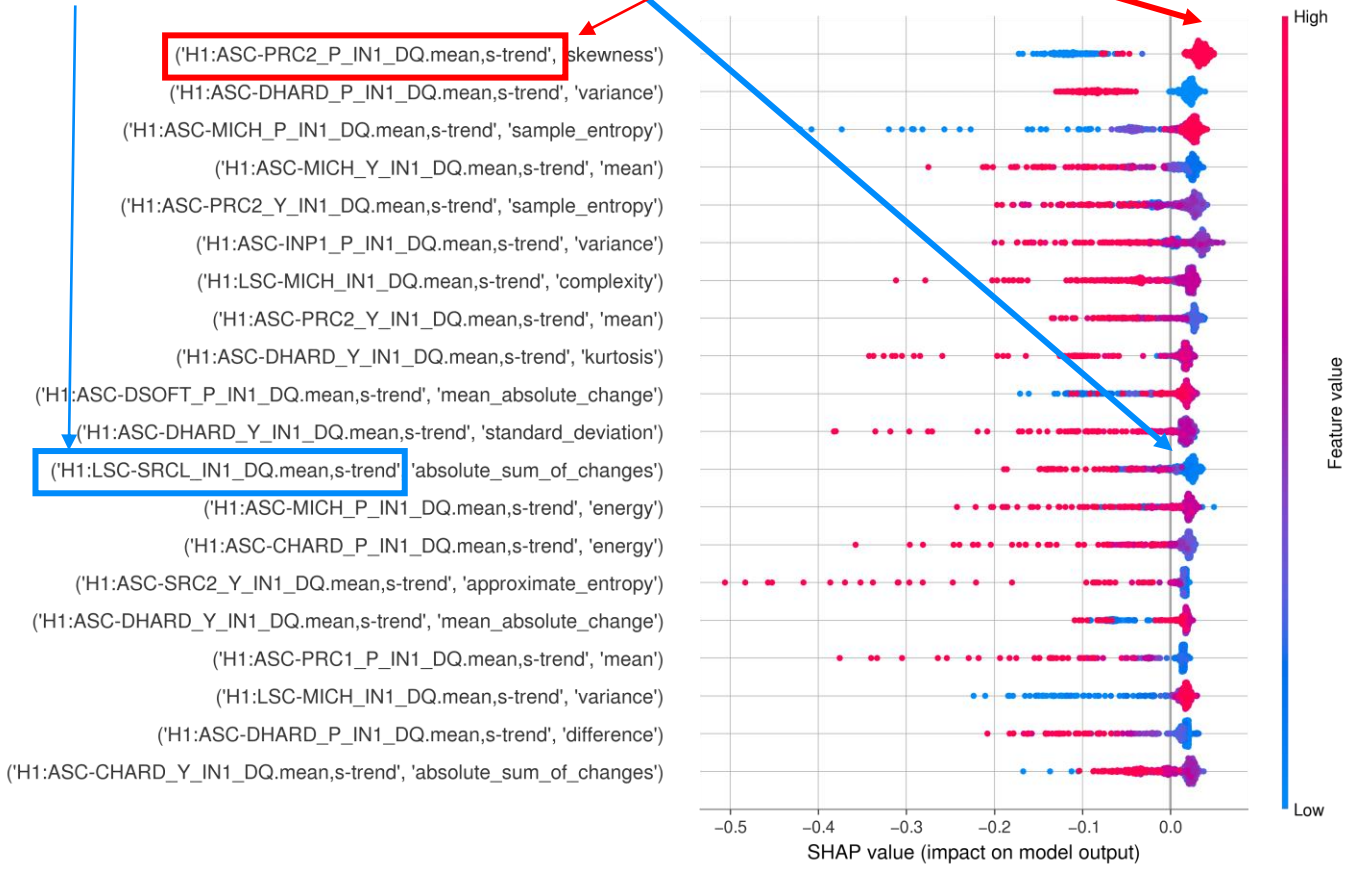
Determine important channels using Shapley values

Low values of this channel's absolute sum of changes has +ve impact on model prediction

High values of this channel's skewness has +ve impact on model prediction



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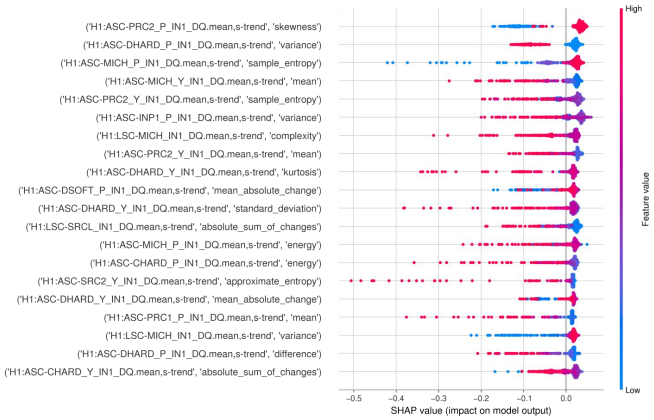
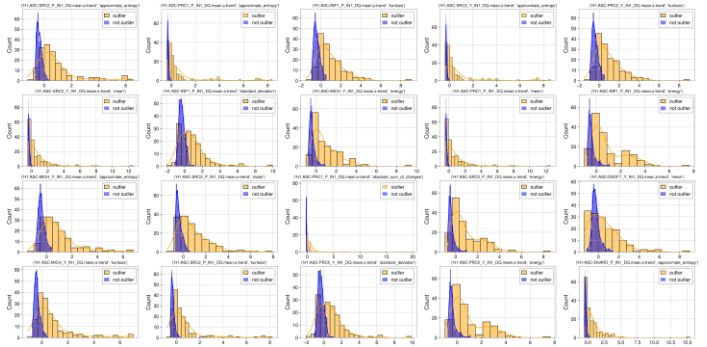
Common important channels for Isolation Forest:

Shapley values



Surrogate Modelling



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top 20 channels + features

H1:ASC-PRC2_Y_IN1_DQ.mean,s-trend
H1:ASC-INP1_P_IN1_DQ.mean,s-trend
H1:ASC-DHARD_P_IN1_DQ.mean,s-trend
H1:ASC-SRC2_Y_IN1_DQ.mean,s-trend
H1:ASC-MICH_Y_IN1_DQ.mean,s-trend
H1:ASC-PRC1_P_IN1_DQ.mean,s-trend

Common important channels between LOF and Isolation Forest (via Surrogate Modelling):

H1:ASC-MICH_Y_IN1_DQ.mean,s-trend
H1:ASC-PRC1_P_IN1_DQ.mean,s-trend
H1:ASC-SRC2_P_IN1_DQ.mean,s-trend
H1:ASC-SRC2_Y_IN1_DQ.mean,s-trend

(Follow-up on channels pending)

Preliminary Remarks

- Channels + Features + Data Segments used are not enough to predict ALL types of locklosses that occurred at Hanford in O3a

1. Summary statistics of a data segment of the mean, s-trend of a channel may wash out finer resolution features.
2. 23 length and angular degrees of freedom channels used may not witness all locklosses.
3. SEGMENT_LENGTH and SEGMENT_BUFFER used may miss predictive features outside that window.

Future Directions

- The search across {**SEGMENT LENGTH, SEGMENT BUFFER}** combinations is expensive
  - Matrix Completion to the rescue?
- Appropriate pre-processing
  - Corner frequencies for each channel?
- Better features
  - Hand-crafted vs **DNN for feature extraction**
  - **Continuous Wavelet Transform Scalogram** to capture 'bursty' and slow information from each segment of each channel.
- Silver Bullet or Ensemble?

  Expand channels list

  BUT…

  Silver Bullet model using all channels?

  OR

  Smaller models ensembled together?