Real-Time Outlier Detection with Dynamic Process Limits

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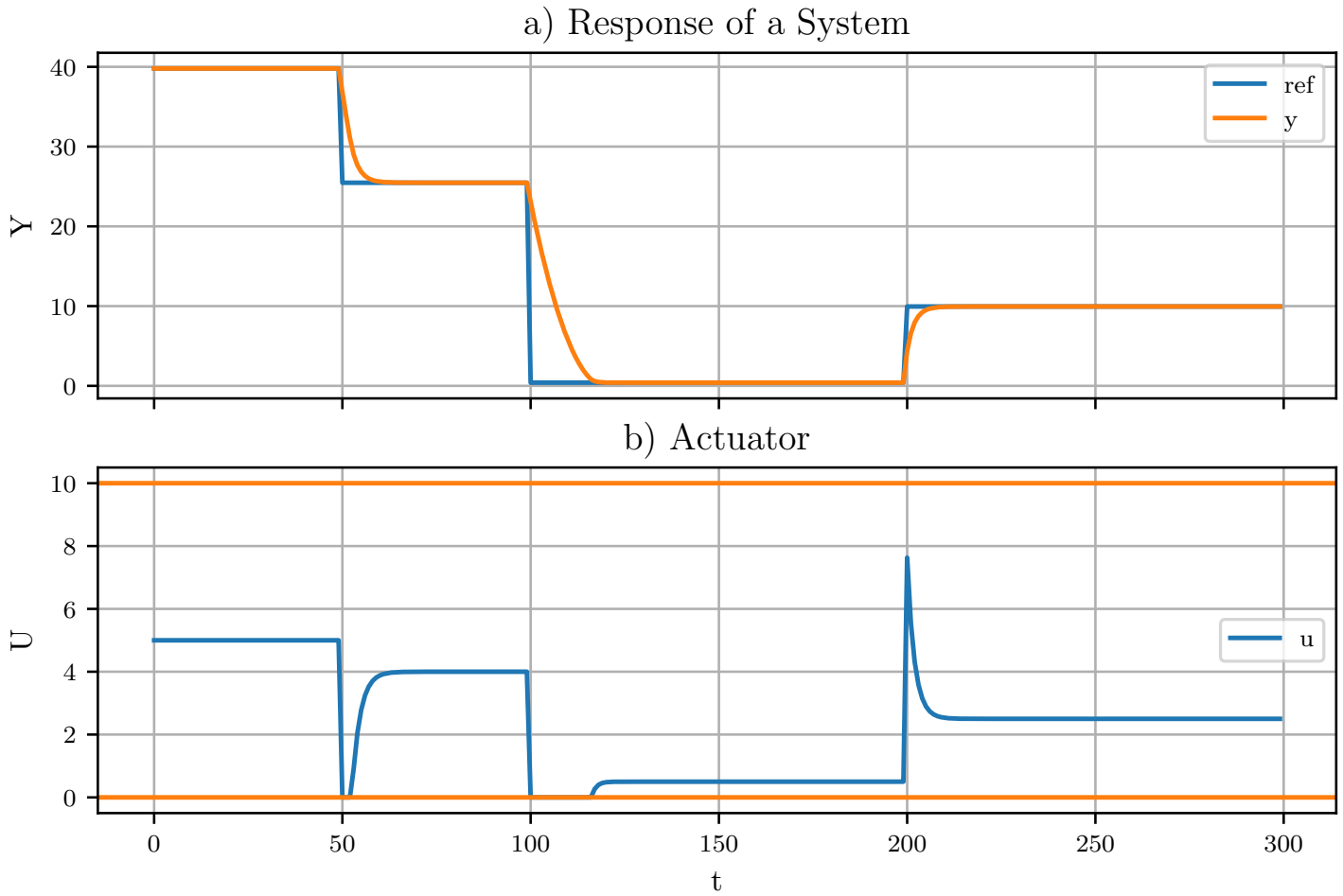
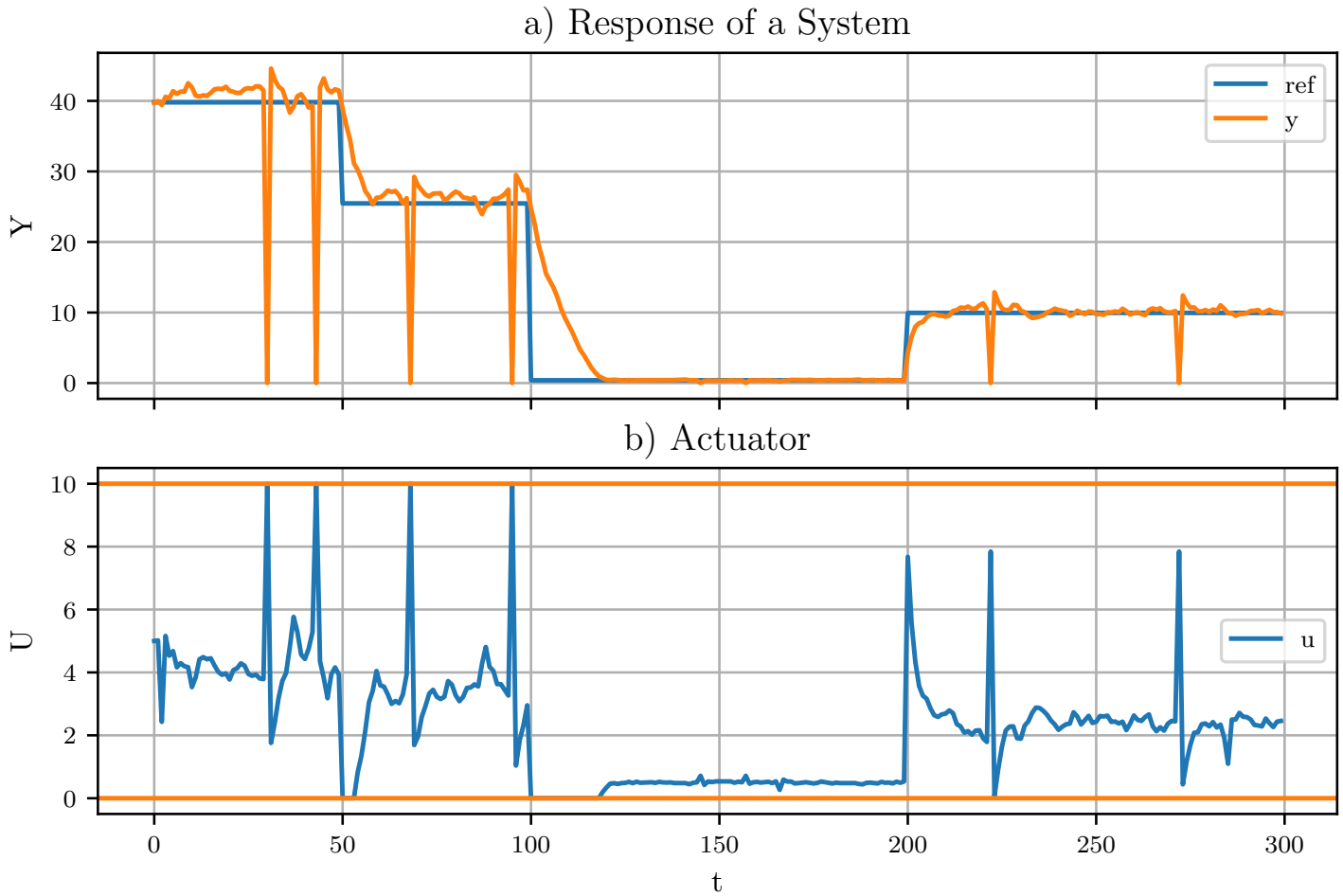
FACULTY OF CHEMICAL AND FOOD TECHNOLOGY

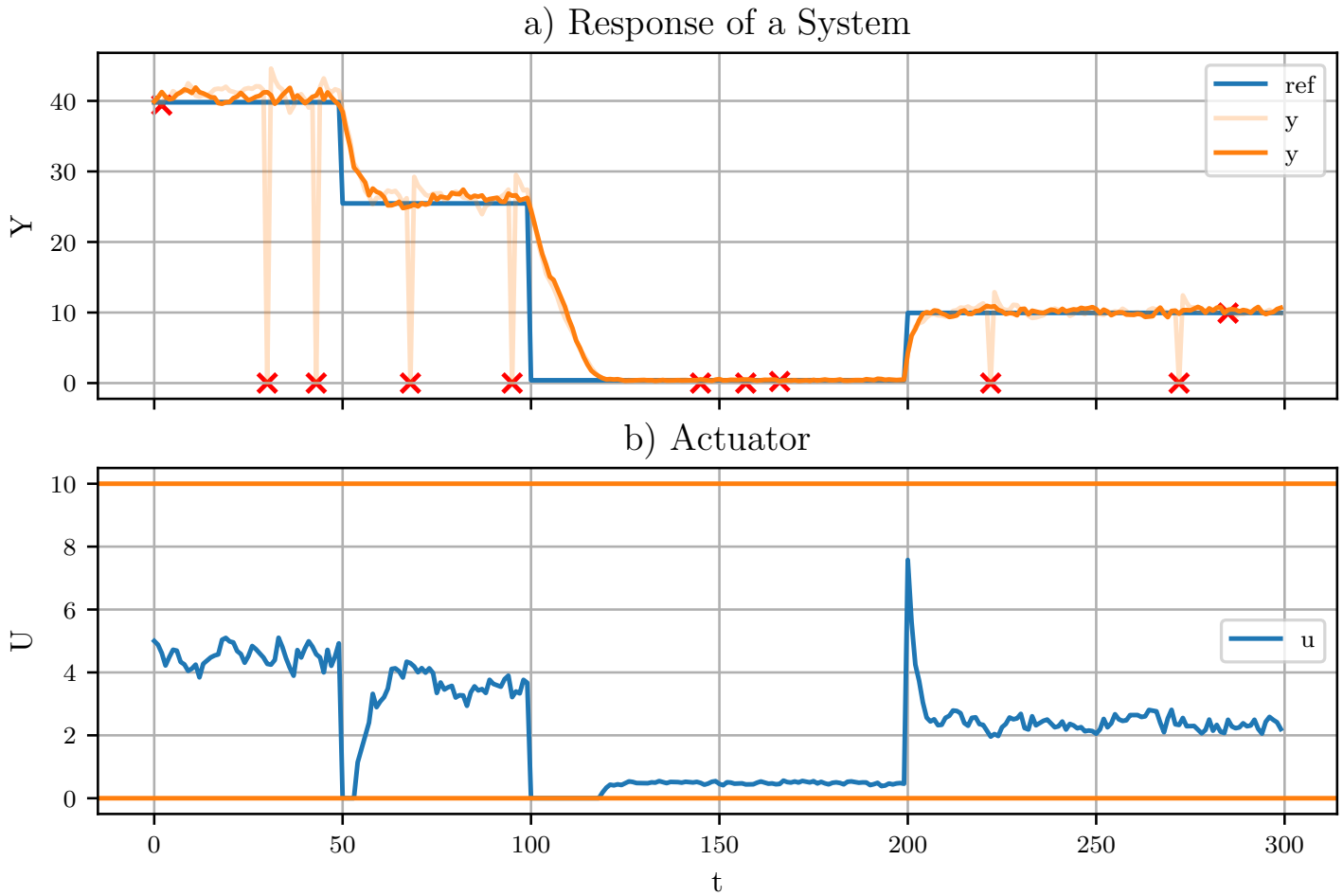
Control Engineering meets Artificial Intelligence



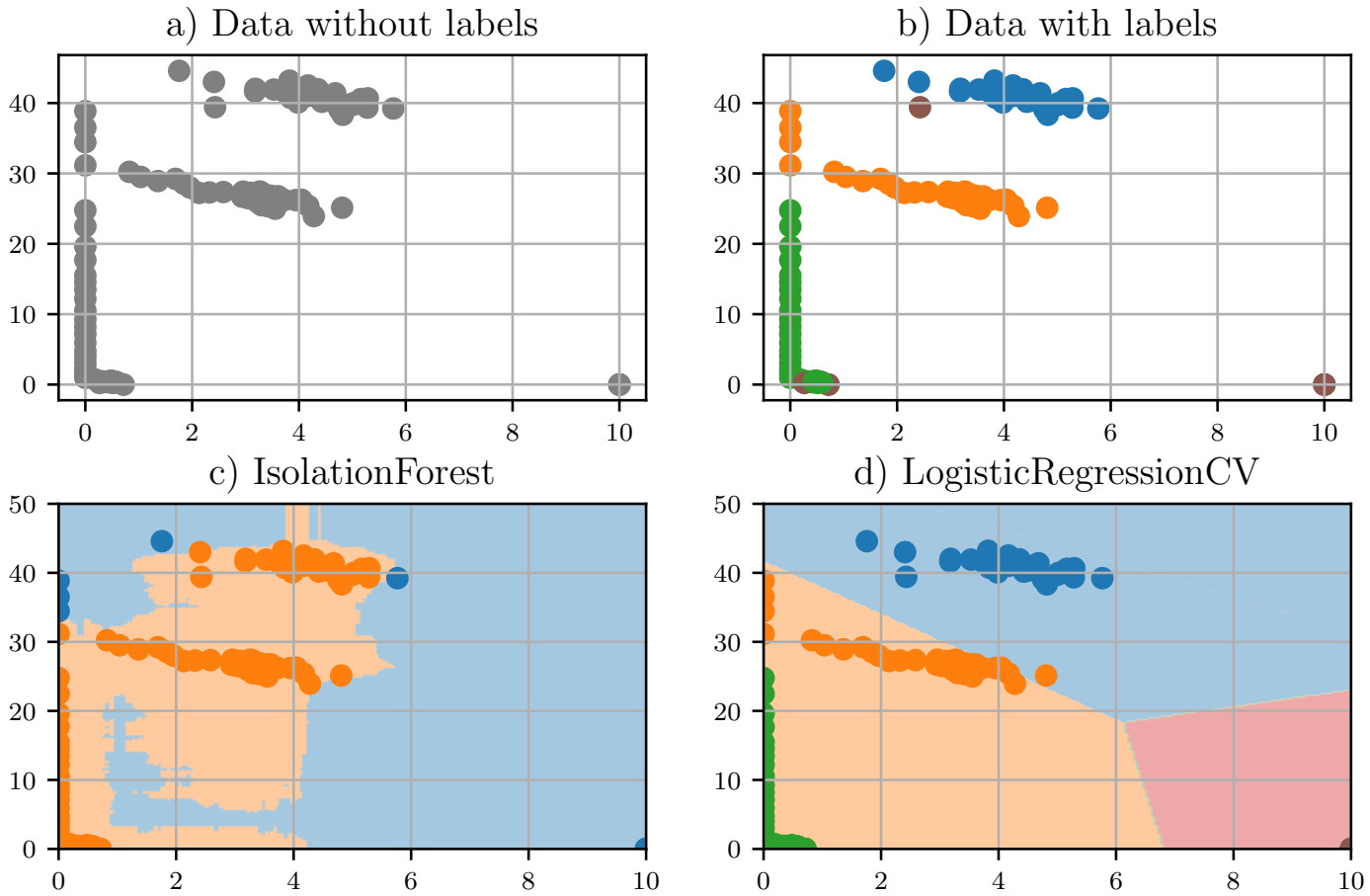
Coming Problem



Emotional Win



Drawbacks of Existing Solutions



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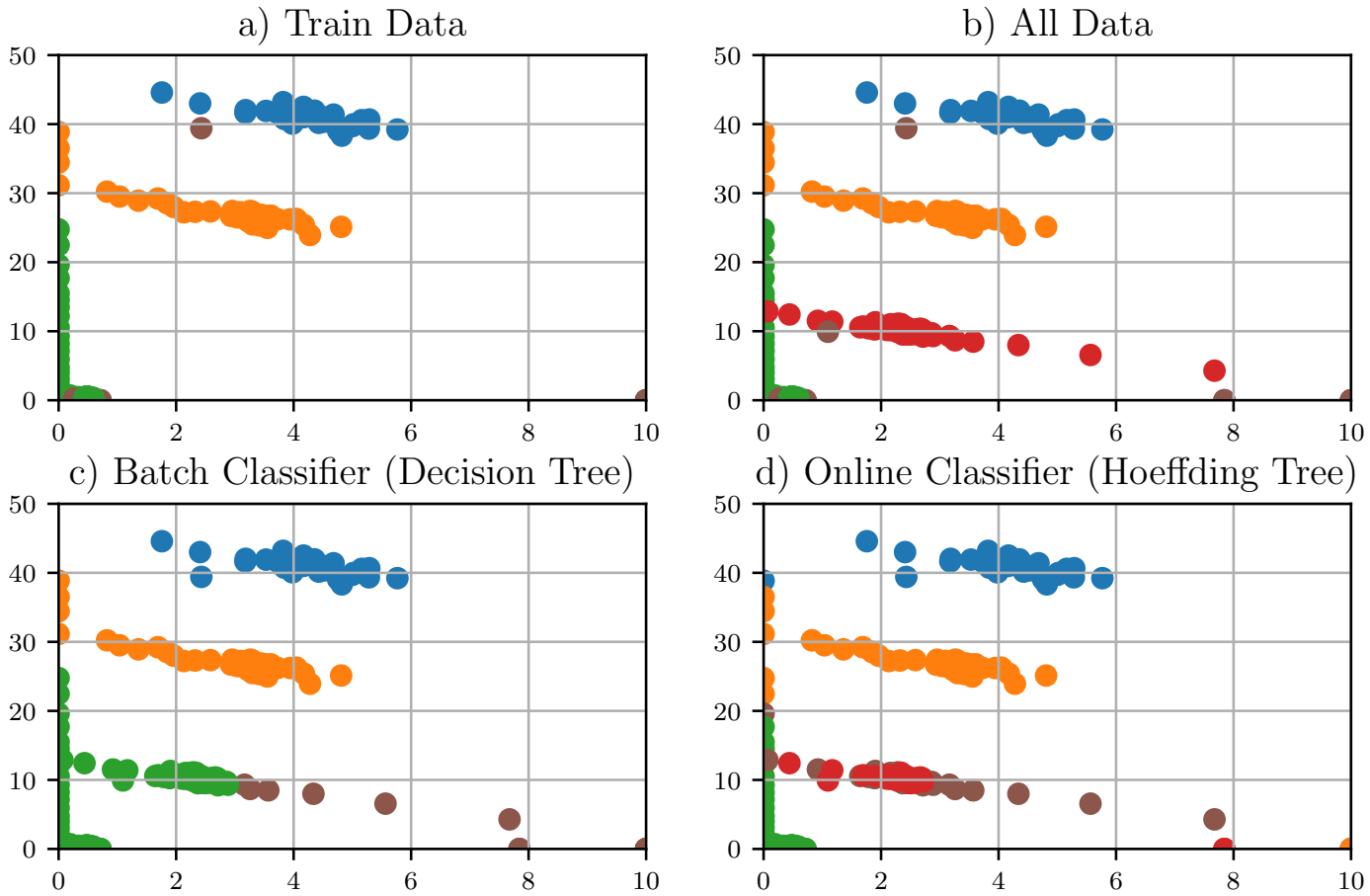


Audacious Reality

We need to make detector that:

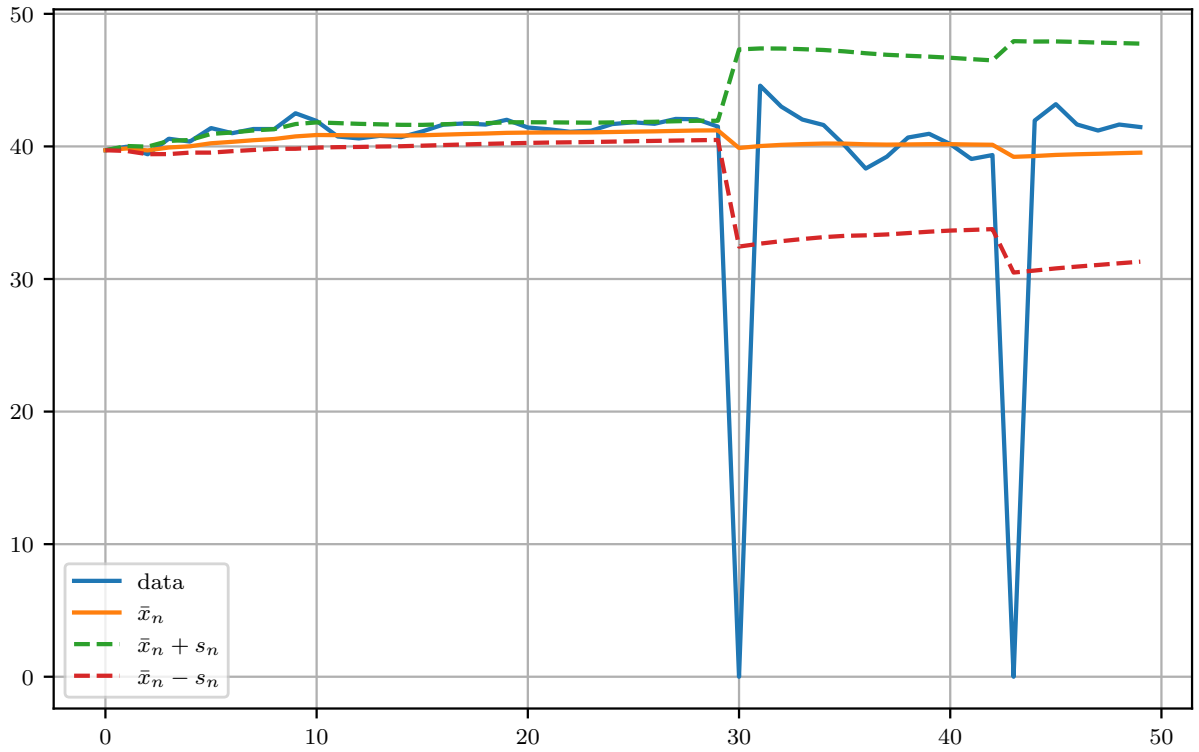
- Does not require huge amount of data
- Adapts to unseen operation
- Offers credible interpretation
- Does not alter operation of existing systems
- Improves maintenance scheduling

Proposed Solution

Combine:

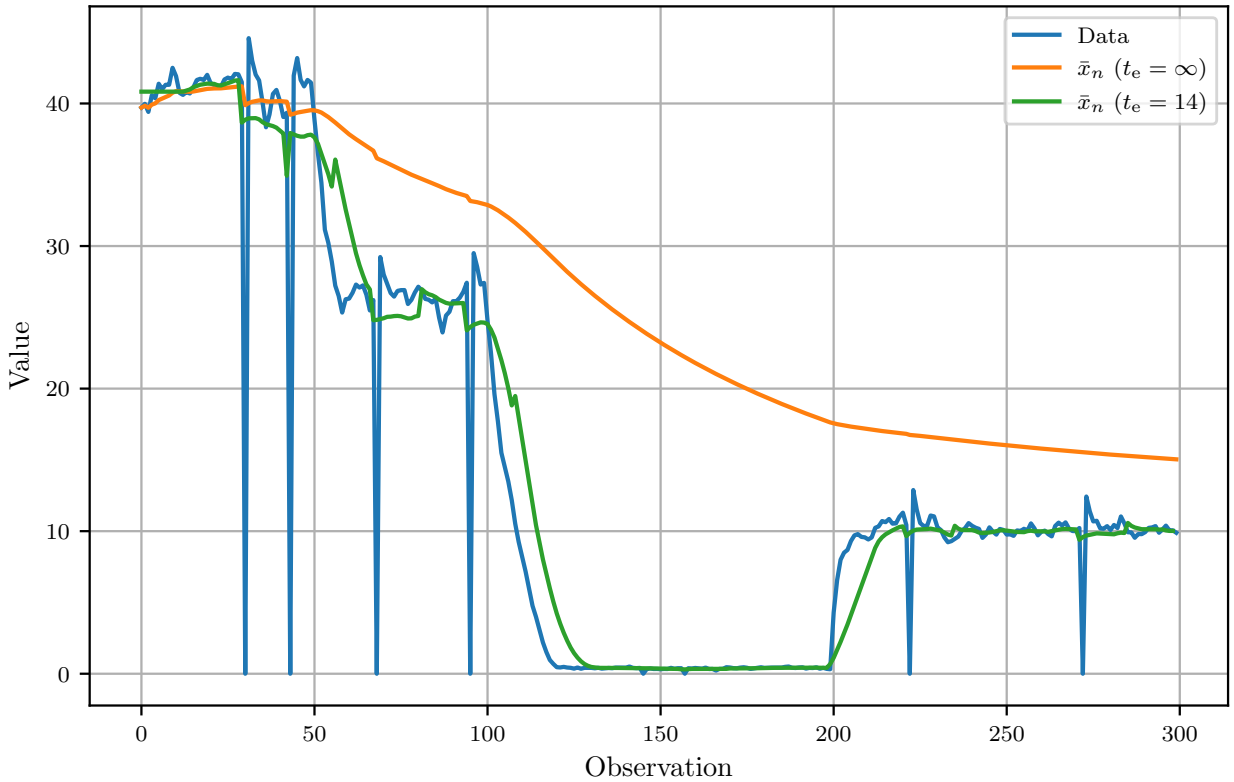
- Incremental Learning
- Anomaly Detection
- Interpretable Probabilistic Model

Welford Algorithm



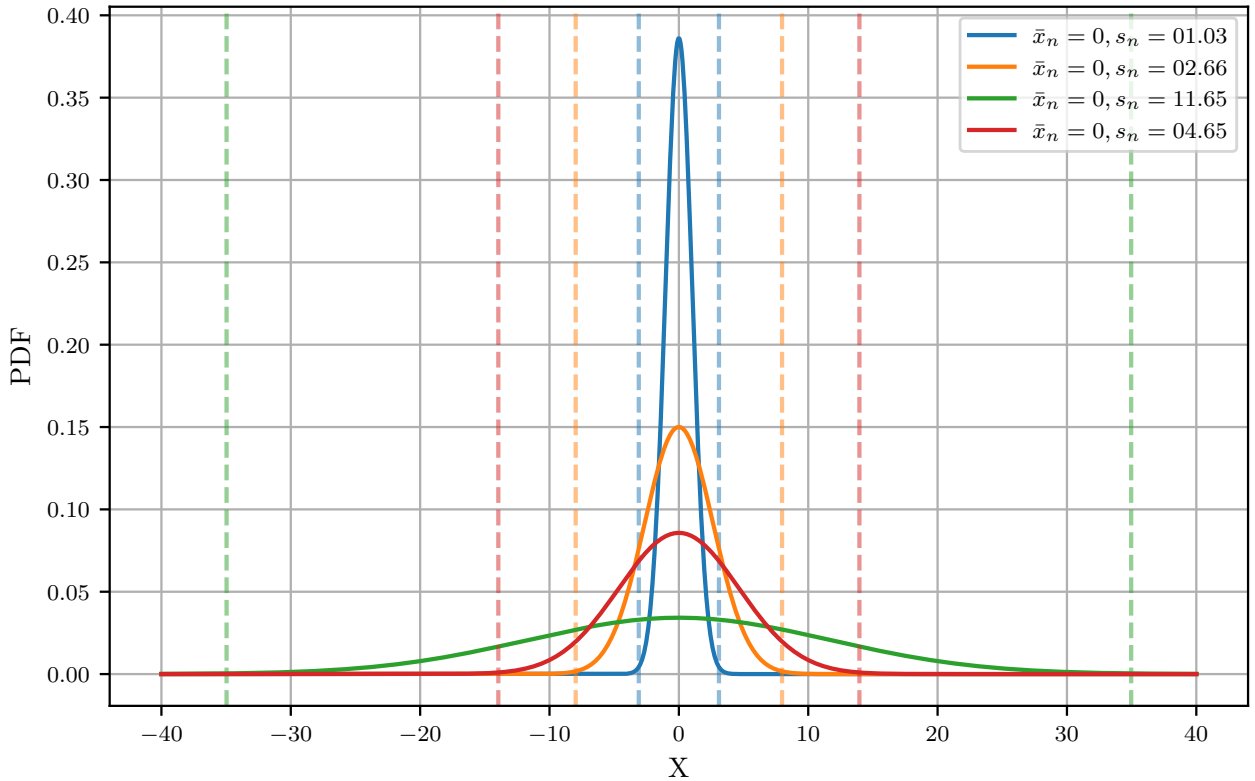
\+ One-Pass Algorithm | − Adaptation Slows Down

Inverse Welford Algorithm



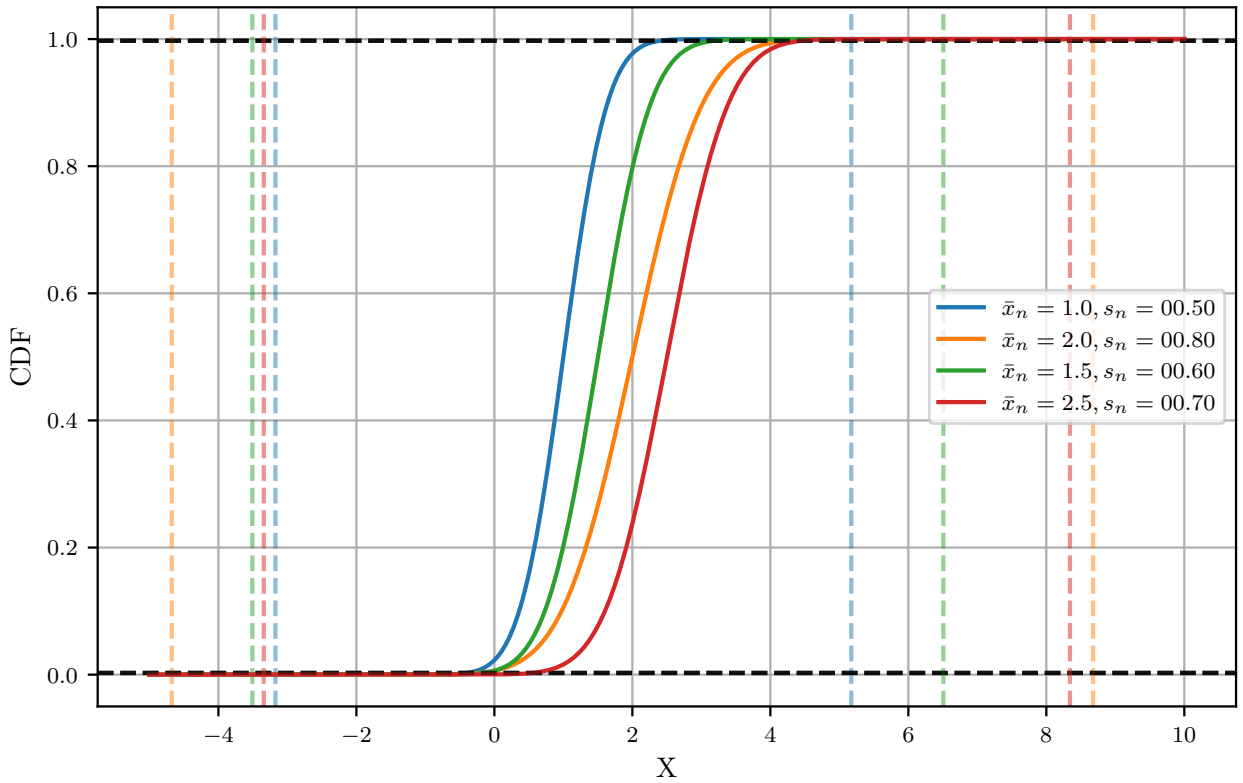
\+ Constant Adaptation | − Memorizes Data Window

Deviation-based Detection



$$y_i = \begin{cases} 0 & \text{if } q \leq F_X(x_i; \bar{x}_n, s_n), \quad (1a) \\ 1 & \text{if } q > F_X(x_i; \bar{x}_n, s_n). \quad (1b) \end{cases}$$

Inversion of CDF



$$x_{\mathrm{l}} = F_X(1-q;\bar{x}_n,s_n)^{-1},$$
$$x_{\mathrm{u}} = F_X(q;\bar{x}_n,s_n)^{-1}.$$

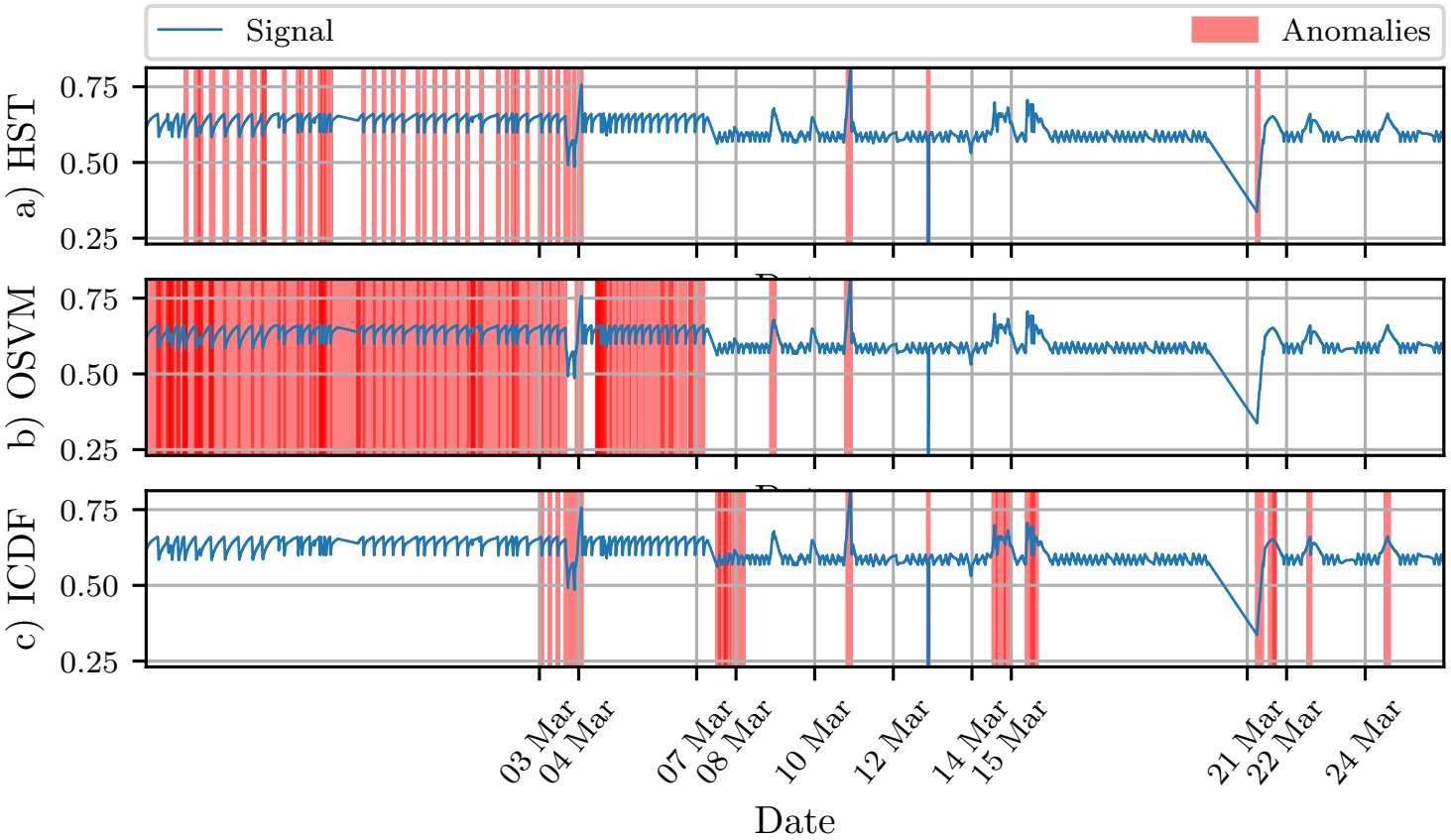
Online Anomaly Detection Workflow

Input: expiration period t_e, time constant t_c
Output: score y_i, threshold $x_{q,i}$

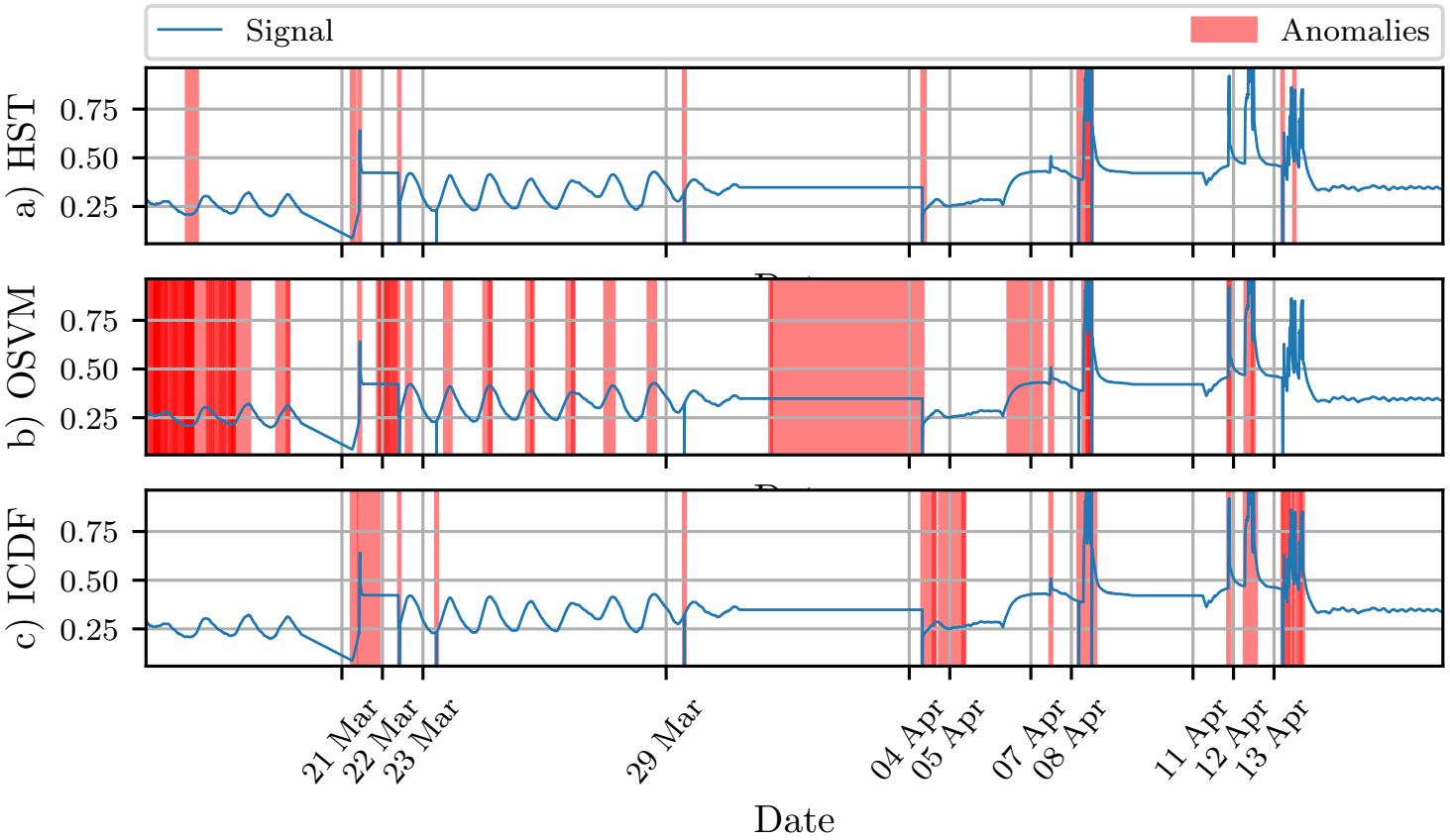
Initialisation :

$i \leftarrow 1;\ n \leftarrow 1;\ q \leftarrow 0.9973;\ \bar{x} \leftarrow x_0;\ s^2 \leftarrow 1;$
compute $F_X(x_0)$;
LOOP Process
loop
  $x_i \leftarrow$ RECEIVE();
  $y_i \leftarrow$ PREDICT(x_i) ;
  $x_{q,i} \leftarrow$ GET$(q, \bar{x}, s^2)$;
  if (1a) **or** $\sum_{y \in Y} y/n(Y) > q$ **then**
    $\bar{x},\ s^2 \leftarrow$ UPDATE$(x_i, \bar{x}, s^2, n)$;
    $n \leftarrow n + 1$;
    for x_{i-t_e} **do**
      $\bar{x},\ s^2 \leftarrow$ REVERT$(x_{i-t_e}, \bar{x}, s^2, n)$;
      $n \leftarrow n - 1$;
    end for
  end if
  $i \leftarrow i + 1$;
end loop

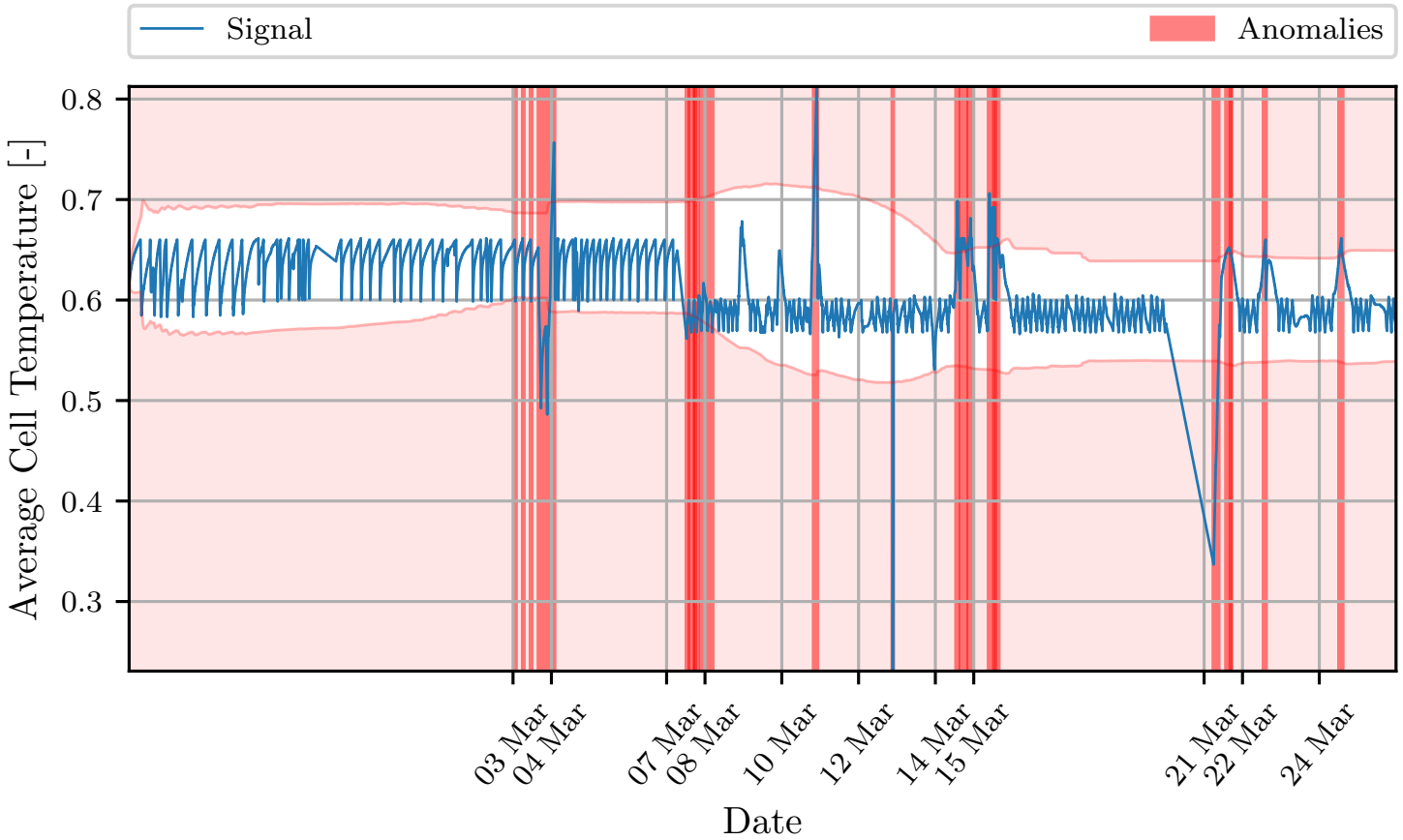
ICDF-based Outlier Detection - BESS



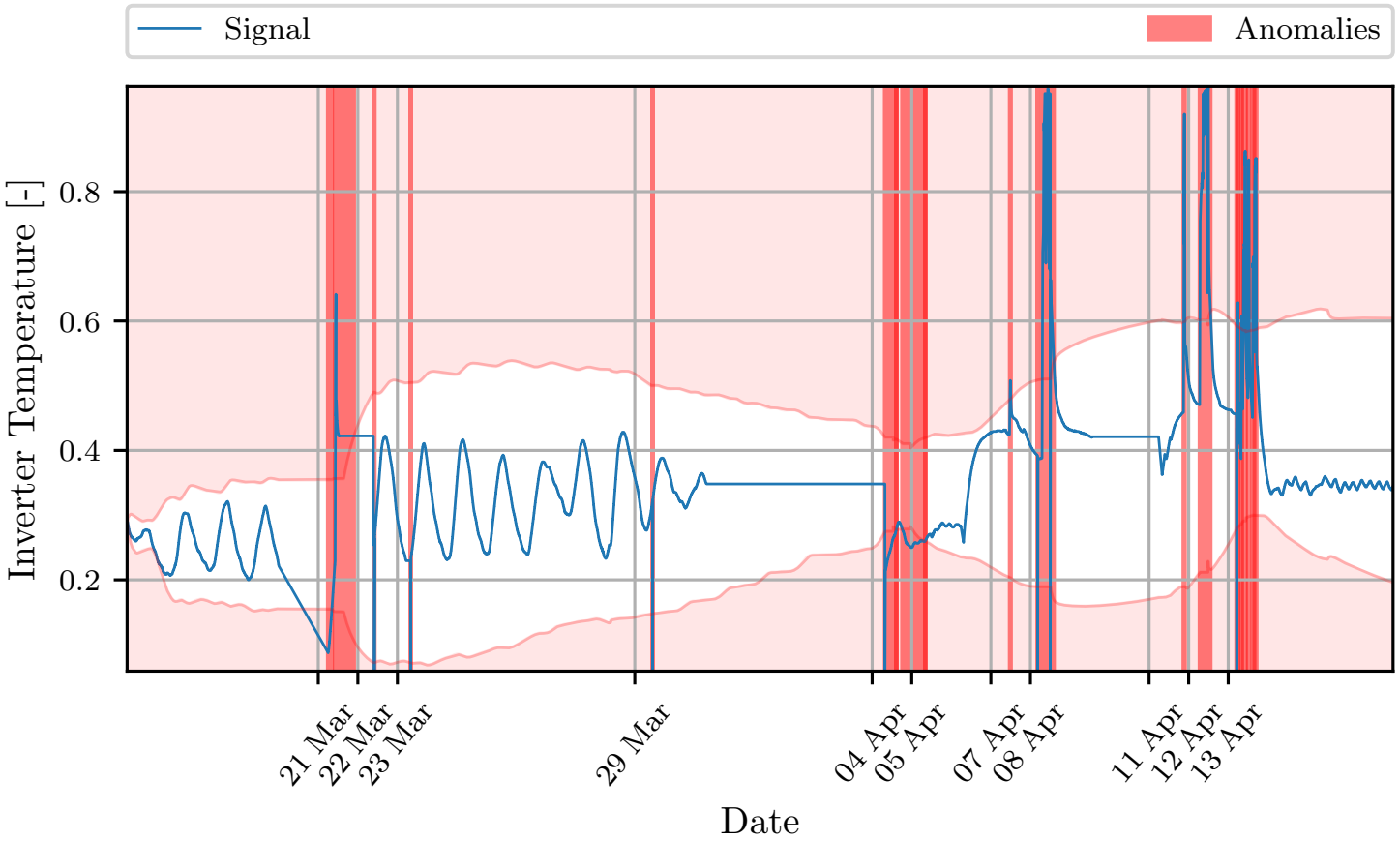
ICDF-based Outlier Detection - Inverter



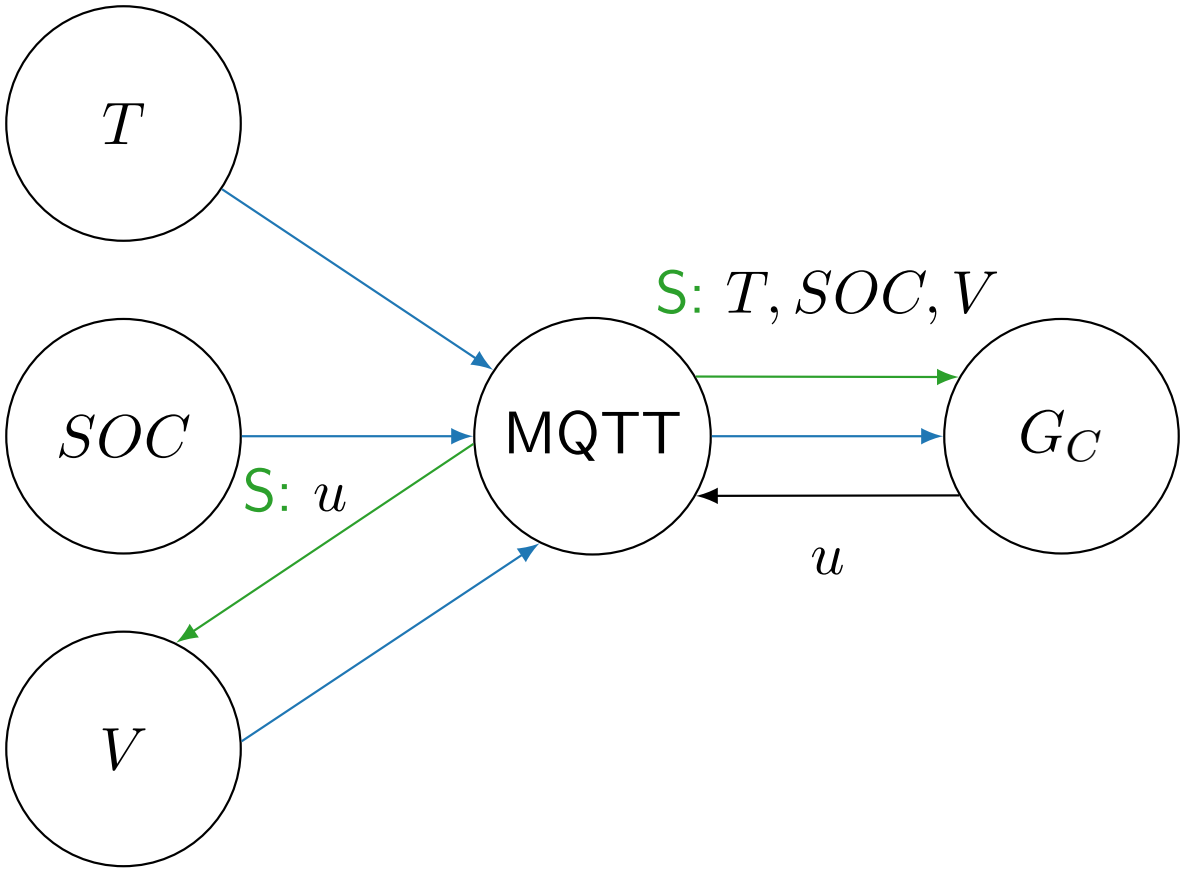
Dynamic Process Limits



Dynamic Process Limits



Utilize Existing Infrastructure



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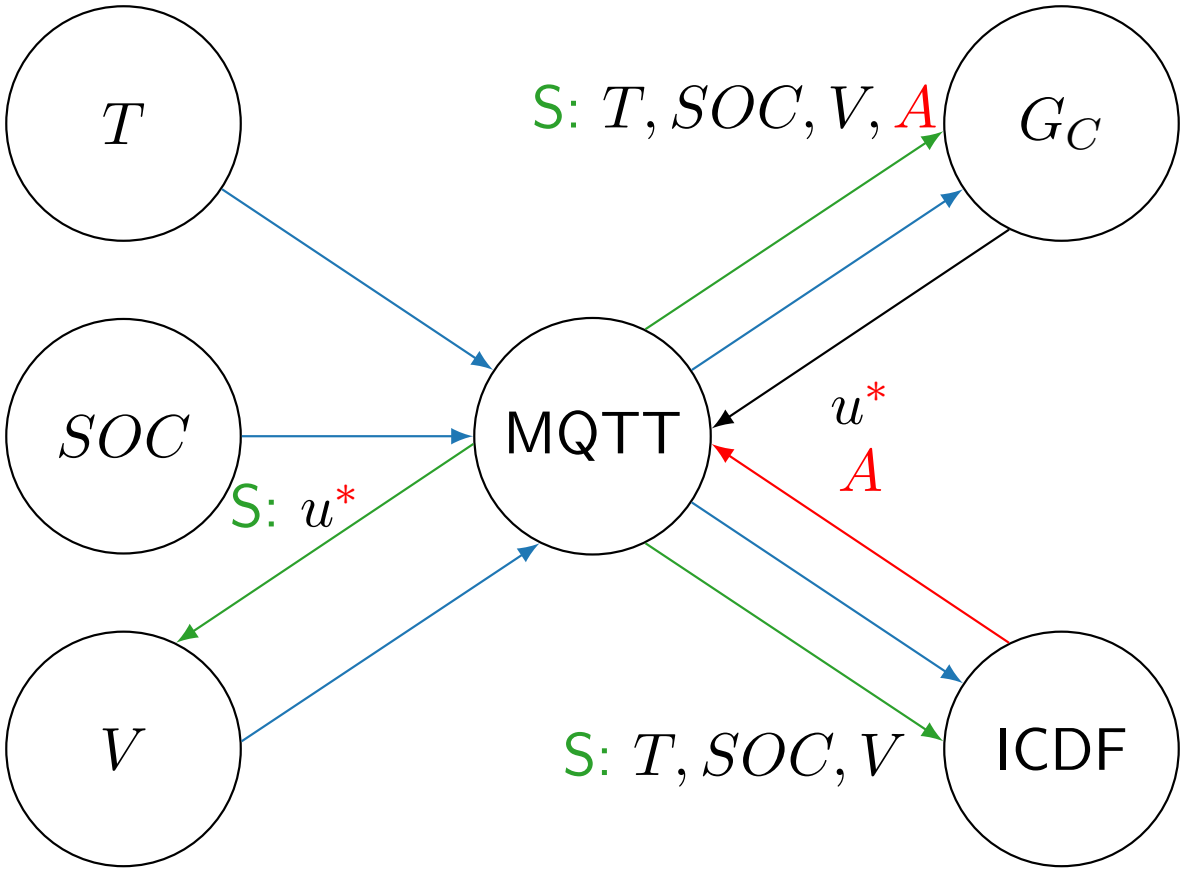
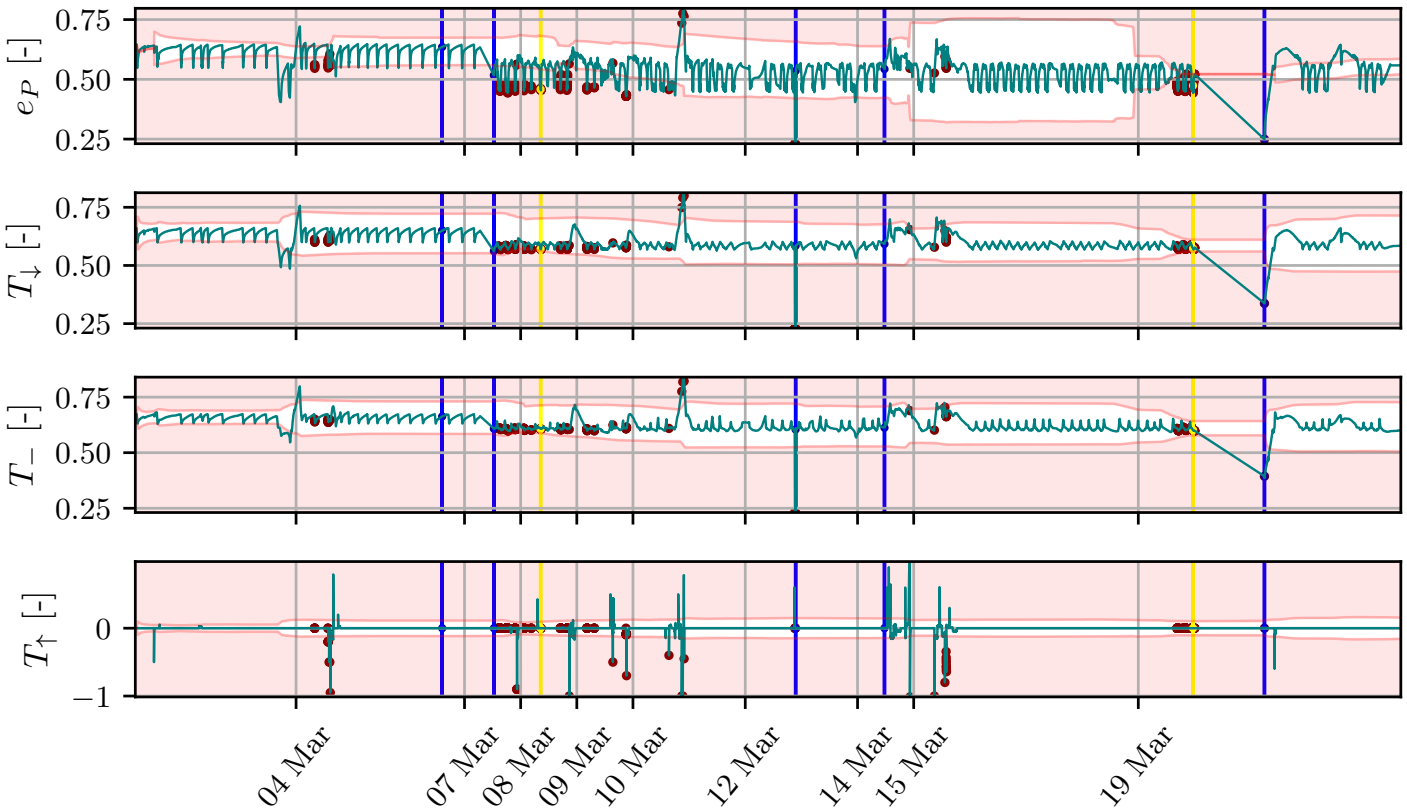


The Long Win



[1]

[1] M. Wadinger and M. Kvasnica. Adaptable and interpretable framework for novelty detection in real-time iot systems. In Proceedings of the 62nd IEEE CDC, Singapore, 2023. under review.

The Long Win

Thank you for Your Attention!