Anomaly Detection, Classification, and Data Recovery in Real-time Monitoring of Large Power Grids

Nilanjan Ray Chaudhuri
Associate Professor, Electrical Engineering
The Pennsylvania State University
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Spurious outliers, missing samples, and malicious injections in PMU sensor data can jeopardize the monitoring and control of power grids
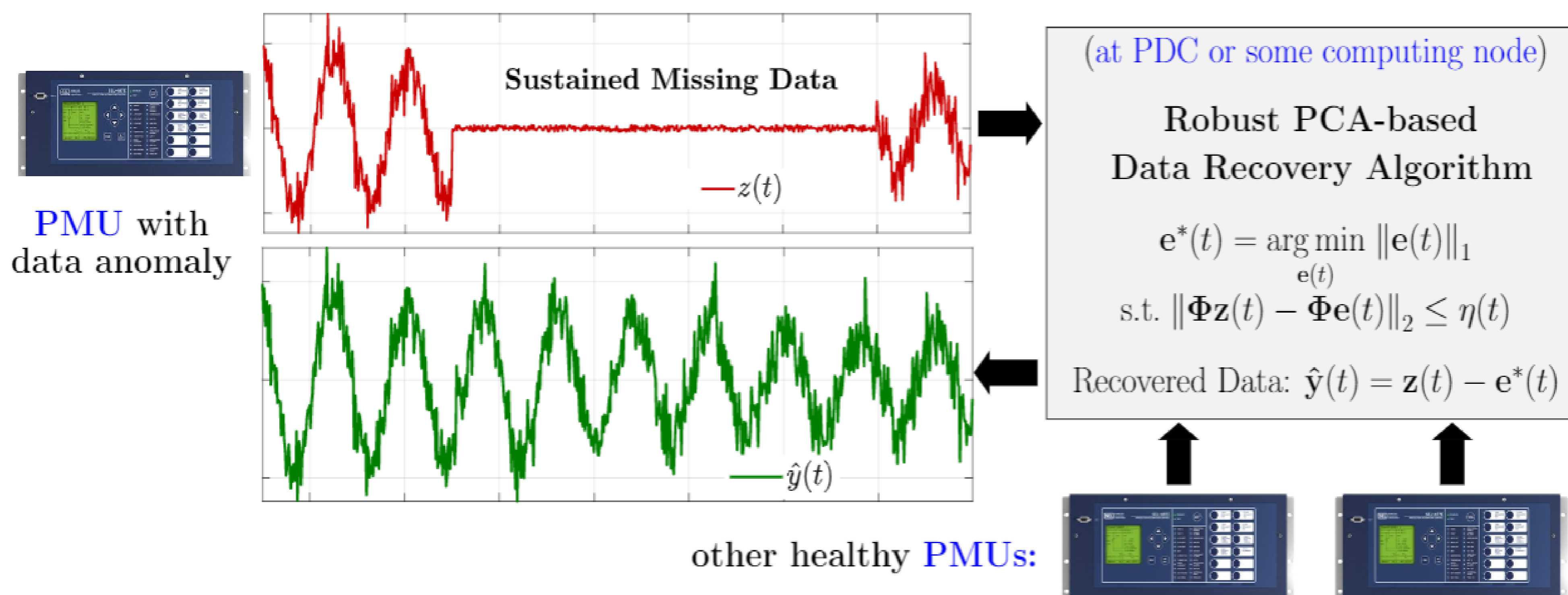
BROADER SCIENTIFIC & SOCIETAL IMPACT

Better visualization of system dynamics to understand the precursors to cascading failures and blackouts

Resilience from cyber-attacks coming from cyber terrorists and enemy nations

KEY CHALLENGES BEFORE ANOMALY DETECTION & CORRECTION

- ☐ Anomalous outliers with similar appearance as event outliers
- ☐ Correction of anomalous data in real time
- ☐ Efficient algorithms with less computational burden
- ☐ Parallelization via adaptive signal grouping

OVERVIEW

PROPOSED IDEAS, CONCEPTS, & SOLUTIONS

- ☐ Kernel PCA-based unsupervised anomaly classification
- ☐ Robust-PCA-based algorithm for data recovery
- ☐ Distributed optimization for distributed data recovery

Sustained Missing Data

— $z(t)$

PMU with data anomaly

— $\hat{y}(t)$

other healthy PMUs:

(at PDC or some computing node)

Robust PCA-based Data Recovery Algorithm

$$\mathbf{e}^*(t) = \arg\min_{\mathbf{e}(t)} \|\mathbf{e}(t)\|_1$$

$$\text{s.t. } \|\mathbf{\Phi}\mathbf{z}(t) - \mathbf{\Phi}\mathbf{e}(t)\|_2 \leq \eta(t)$$

Recovered Data: $\hat{\mathbf{y}}(t) = \mathbf{z}(t) - \mathbf{e}^*(t)$

ATTACKER

Corrupted signal

Data Pre-Processor

Robust PCA   PCP

PDC

Corrected signal to other applications

K-PCA   Event Detection & Classification

Mode Metering Real-Time Control Subspace Library

Learning Based Methods

CONTROL CENTER

PMU

PMU

PMU

NASPI North American SynchroPhasor Initiative

Missing Data, Spurious Outliers GPS Errors, Meter Bias

signal reconstruction

$|V_{18}|$, pu

corrupted
original
proposed

(a)

signal reconstruction

$|V_{45}|$, pu

corrupted
original
proposed

(a)