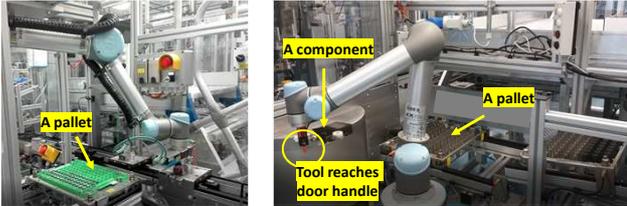# WETSAND – Warped Time Series Anomaly Detection
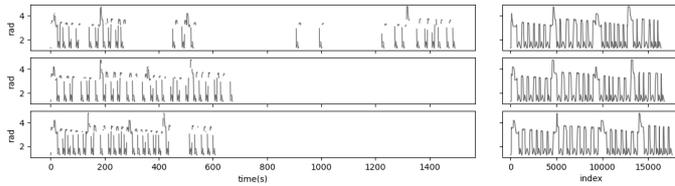
Charlotte Lacoquelle (PhD) Supervisors: Louise Travé-Massuyès, Xavier Pucel, Christophe Merle

Monitoring robots performing repetitive tasks

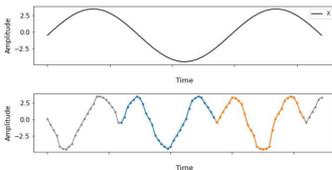**6 axis collaborative robots that perform (de)palletizing**

- Joint positions collected in real time (125 Hz)
- Cycles of different lengths due to the uneven pace in production line
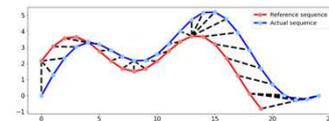- Missing data (around 28%)

Reasoning with time series of different lengths
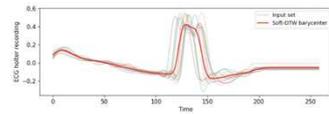
DTW algorithm and variants

DTW computes a distance between times series of different lengths

Subsequence-DTW finds pattern occurrences inside a long time series

Soft-DTW computes a barycenter for a set of signals with different lengths
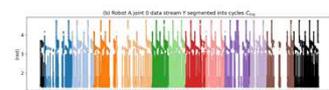
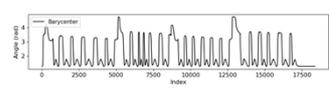## Anomaly detection approach

3 step "golden batch" approach

1. Operator programs the robot
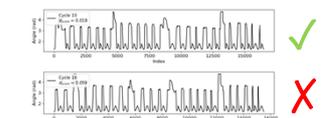Test run provides reference cycle
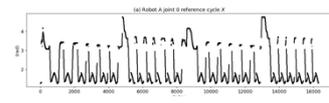
2. Monitor the robot
Segment using subsequence-DTW

3. Compute "golden batch"
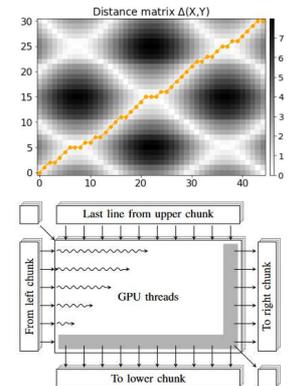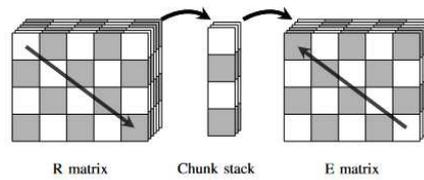Soft-DTW barycenter of first N cycles

4. Detect anomalies
DTW distance to barycenter

GPU Implementation

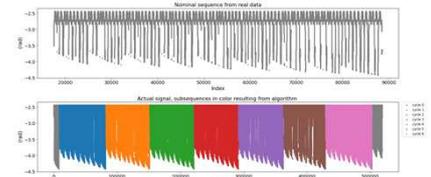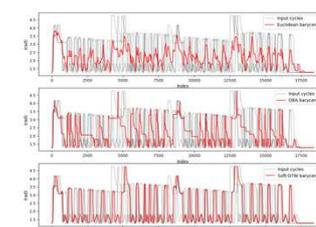**Adaptation of DTW algorithms to large signals**

- DTW computes intermediate matrices
- For large signals (> 15k), large matrix (128 Go)
- Hyper parameter tuning not sufficient
- GPU CUDA implementation
- 2400x speed up (4h → 10mn) for barycenter

Experimental validation

Segmentation works with real data

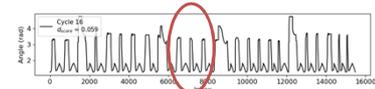- Robust to missing data

Barycenter is a good golden batch

- Represents the intended movement
- Robust to abnormal input
- Better than Euclidean mean or DBA

Anomaly Detection works well

- Interpretable by operators
- Scales to large signals (> 15 000 time steps)
- Frugal (needs as few as 5 training cycles)
- Outperforms AutoEncoders, Transformers on our robots' data

About the ADDX Chair

Principal Investigator: Louise Travé-Massuyès

Co chairs: Jean-Bernard Lasserre, Elodie Chanthery, Carine Jauberthie, Xavier Pucel

Partners:

CNES, Airbus, Schaeffler, IMT, Aumovio, IUCT-Oncopole, ATOS, Carl Levrault, Quantom

Phds, ongoing and completed:

- Christoffel Function based Anomaly Detection for Satellite Telemetry, *GRIVET Florian*
- Explainable GNNs for Anomaly Detection and Diagnosis, *OZGUNAY Sena*
- Machine learning for design and tests in production environments, *BILLET Léa*
- AI, data fusion for diagnosis and flight variables estimation, *LIMA LOPES Lucas Gabriel*
- Unsupervised Multimodal Learning for Fault Diagnosis and Prognosis, *POUJADE Kelian*
- Model validation and enhancement for health monitoring, *HATTE Léonie*
- ✓ Machine learning based radiation hardening of space electronics, *DORISE Adrien*
- ✓ Knowledge-Enhanced Machine Learning for Diagnosis, *GOUPIL Louis*
- ✓ Warped Time Series Anomaly Detection, *LACOQUELLE Charlotte*
- ✓ Outlier detection in data streams in wireless sensor networks, *DUCHARLET Kévin*
- ✓ Detection and diagnosis in photovoltaic power plants, *SEPULVEDA-OVIEDO Edgar H.*
- ✓ Process mining for knowledge extraction and process optimization, *DUONG Le Toan*