Dealing with irregularly sampled and distorted data for anomaly detection of industrial robots

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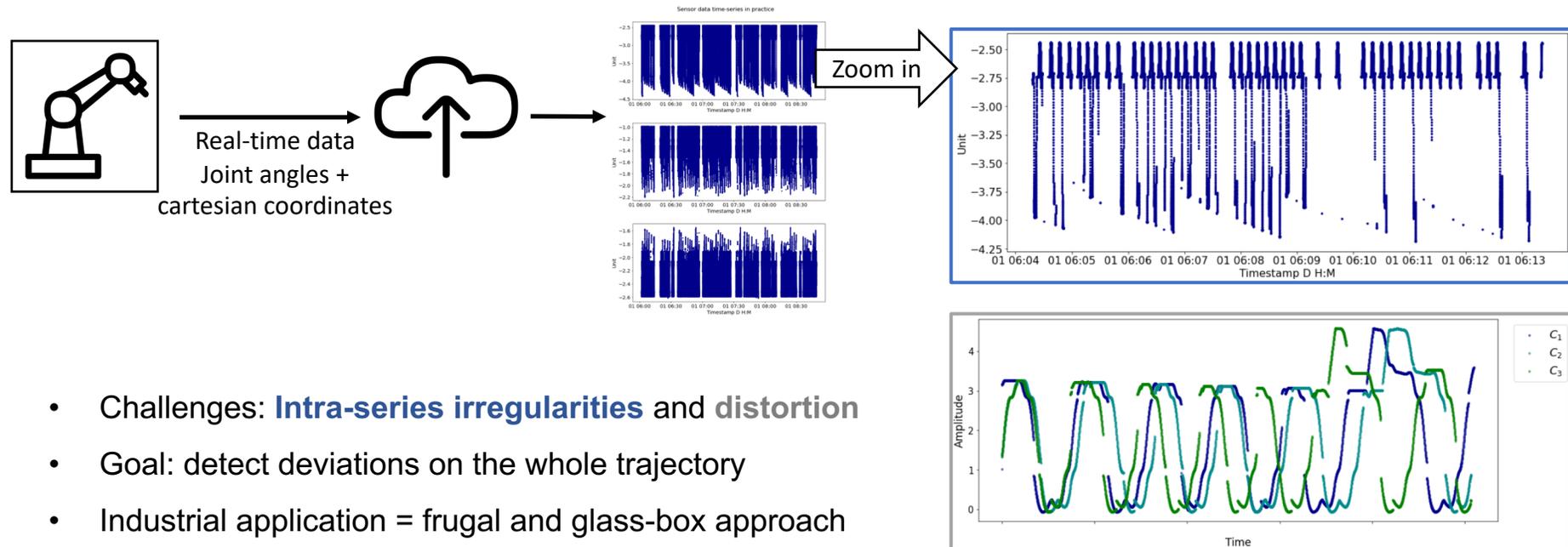
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Diagnosis of cyclic behavior systems

Industrial context and challenges

- A monitoring platform will connect 800 cobots from VT plants with a diagnosis and predictive solution

- Challenges: **Intra-series irregularities** and **distortion**
- Goal: detect deviations on the whole trajectory
- Industrial application = frugal and glass-box approach

How can we identify outliers from a set of irregular and distorted trajectories ?

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Assessing the similarity between irregularly sampled time series

Dynamic Time Warping (DTW):

- The best similarity measure for distorted signals: it **maps their elements non-linearly** by finding the optimal warping path π_{opt}
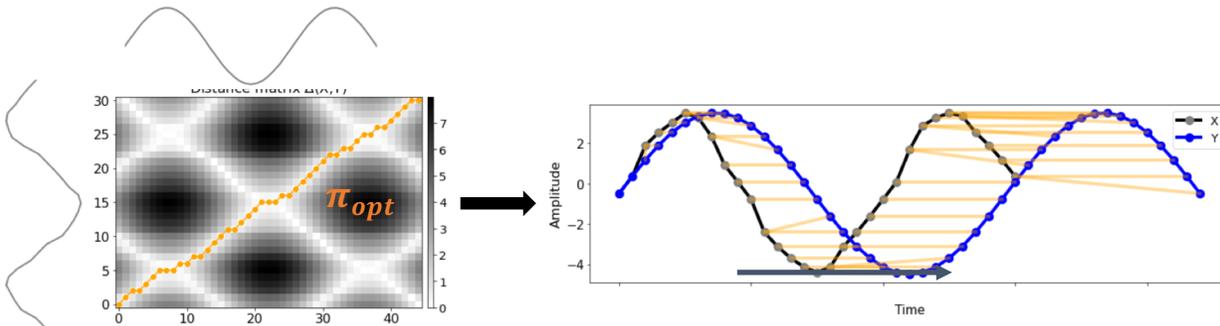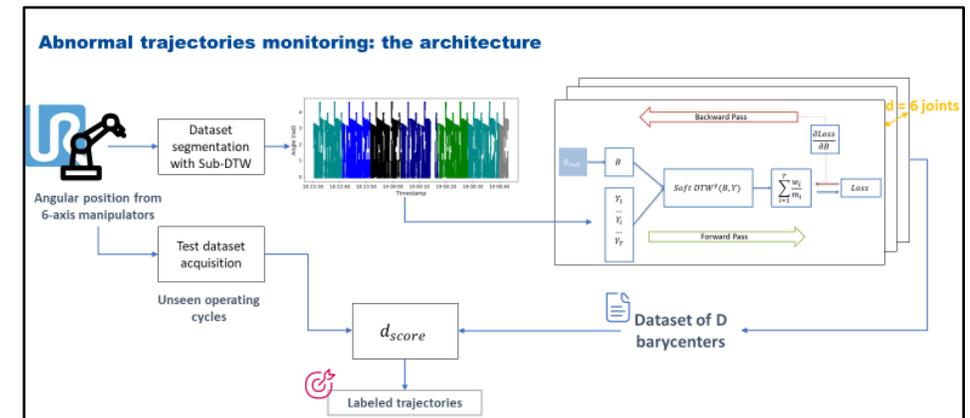

Variants:

- **Subsequence-DTW**: search for a **pattern** allowing temporal distortions

- **Soft-DTW**: a **differentiable version** of the DTW measure, designed to be used in an optimization pipeline.
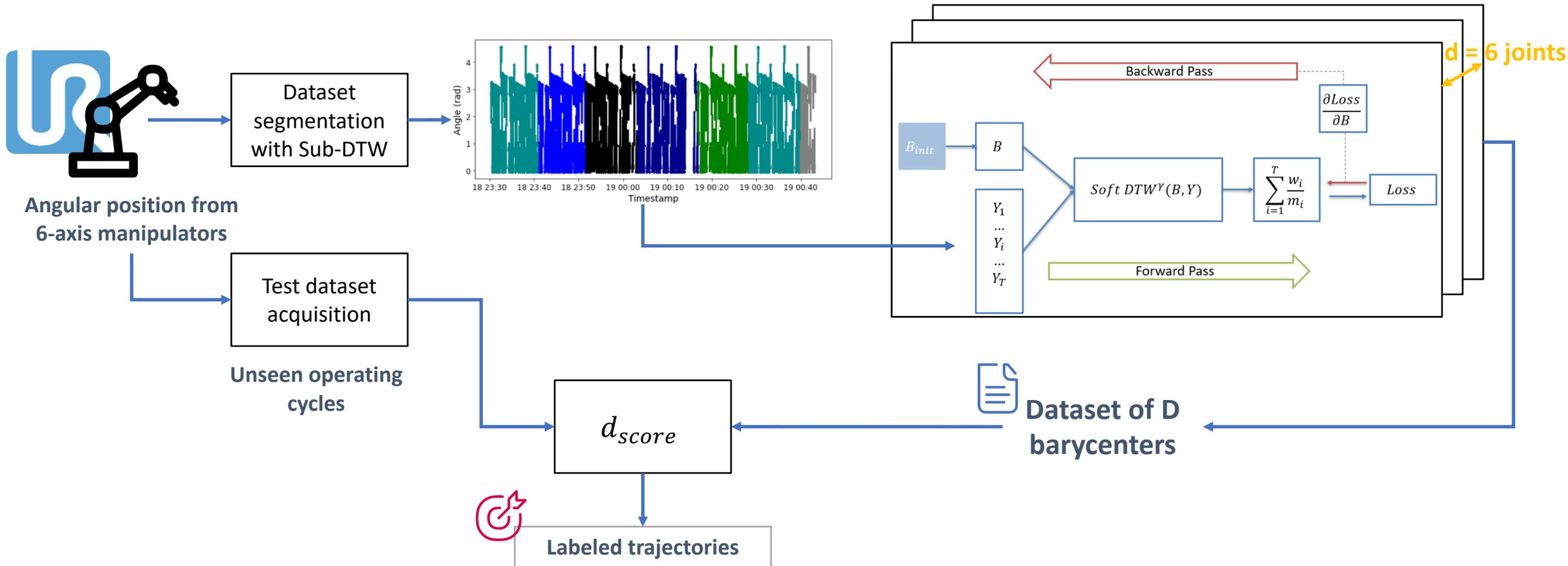
Solution proposal

1. Segmentation based on Subsequence-DTW

2. Synthesis of a **reference trajectory**

3. **Outlier detection** based on a similarity score between the designed reference and the monitored cycles

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Abnormal trajectories monitoring: the architecture

Angular position from 6-axis manipulators

Dataset segmentation with Sub-DTW

Test dataset acquisition

Unseen operating cycles

d_{score}

Labeled trajectories

d = 6 joints

Backward Pass

B_{init} → B

$\frac{\partial Loss}{\partial B}$

Y_1 ... Y_i ... Y_T

$Soft\ DTW^\gamma(B,Y)$

$\sum_{i=1}^{T} \frac{w_i}{m_i}$

Loss

Forward Pass

Dataset of D barycenters

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Trajectories labeling: some results

- The barycenter of each joint is trained with a set of 20 cycles
- The d_{score} is computed between results and a test set of 70 unseen cycles
- Threshold: 2 std + mean
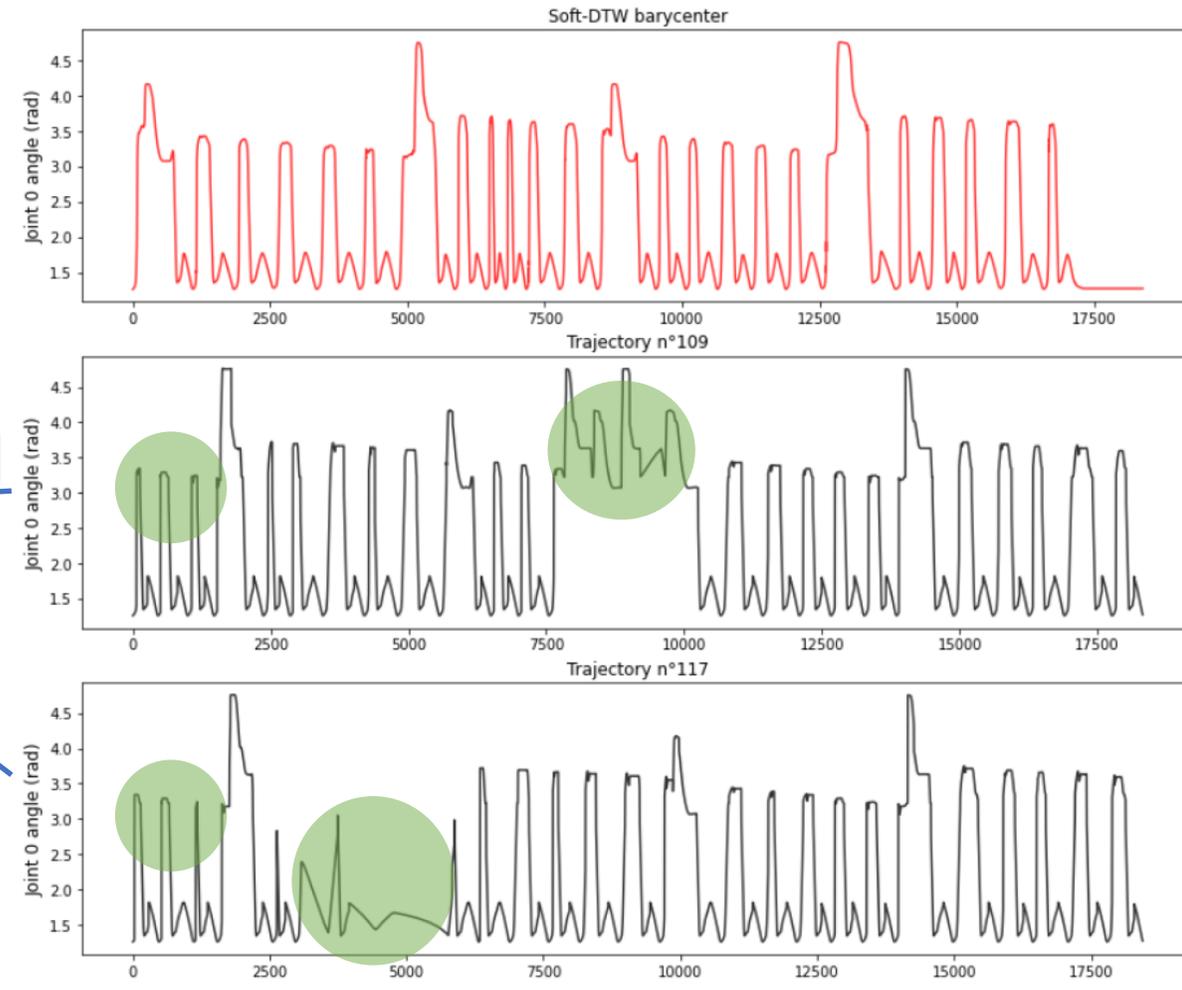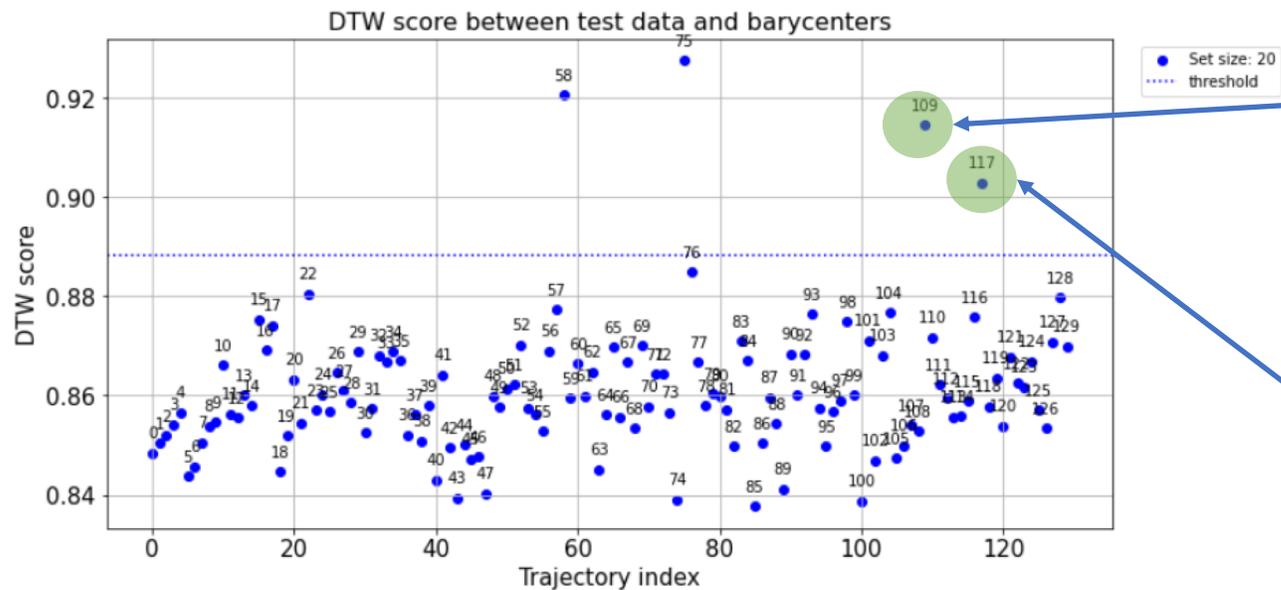
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Diagnosis of cyclic behavior systems

Conclusion

- Framework based on Sub- and Soft-DTW can:
  - Identify cycles
  - Synthesize a prototype
  - Detect abnormal trajectories

- This approach is explainable

- Possibility to find the root cause with the warping path

- Convergence is fast

Future work

- Ongoing work on a GPU-based parallelization of Soft-DTW

- Ongoing evaluation of the results depending on the quality and length of the input sequence set

- Comparison with the results of a generative model

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Thank you for listening ☺

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