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► **To cite this version:**

Ikram Chraibi Kaadoud, Lina Fahed, Tian Tian, Yannis Haralambous, Philippe Lenca. Explaining complex system of multivariate times series behavior. Women In Machine Learning WIML @ Neurips 2022, Nov 2022, Louisanne, United States. 2022. hal-03875661

HAL Id: hal-03875661

<https://imt-atlantique.hal.science/hal-03875661>

Submitted on 28 Nov 2022

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Explaining complex system of multivariate times series behavior

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Our paper at **KDIR@IC3K 2022**
 DOI=10.5220/0011363400003335



Abstract

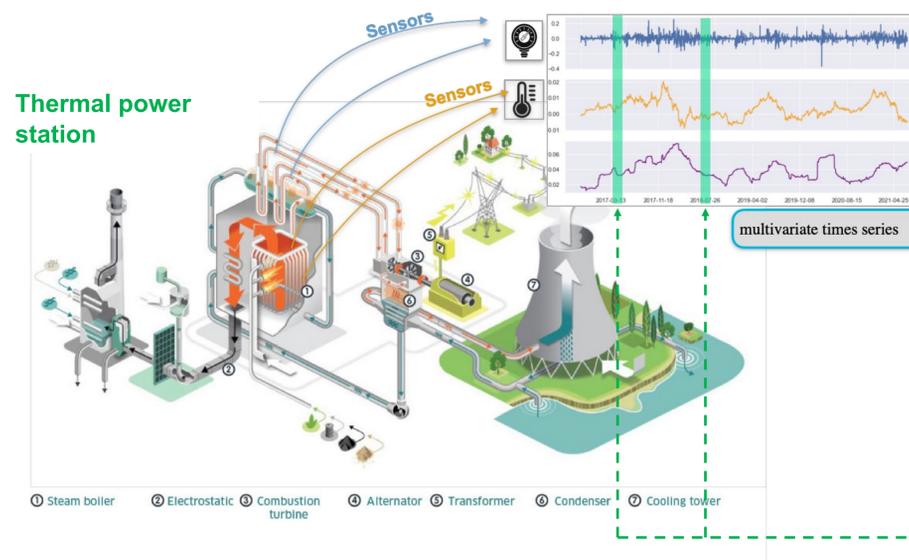
Complex systems represented by multivariate time series are ubiquitous in many applications, especially in industry. **Understanding a complex system, its states and their evolution over time is a challenging task.** This is due to the permanent change of contextual events internal and external to the system. We are interested in **representing the evolution of a complex system in an intelligible and explainable way based on knowledge extraction.**

We propose **XR-CSB (eXplainable Representation of Complex System Behavior)** based on **three steps**:

- (i) a time series vertical clustering to detect system states,
- (ii) an explainable visual representation using unfolded finite-state automata and
- (iii) an explainable pre-modeling based on an enrichment via exploratory metrics.

Four representations adapted to the expertise level of domain experts for acceptability issues are proposed. Experiments show that XR-CSB is scalable. Qualitative evaluation by experts of different expertise levels shows that XR-CSB meets their expectations in terms of explainability, intelligibility and acceptability. This work was presented at KDIR@IC3K 2022 available at the QR code below.

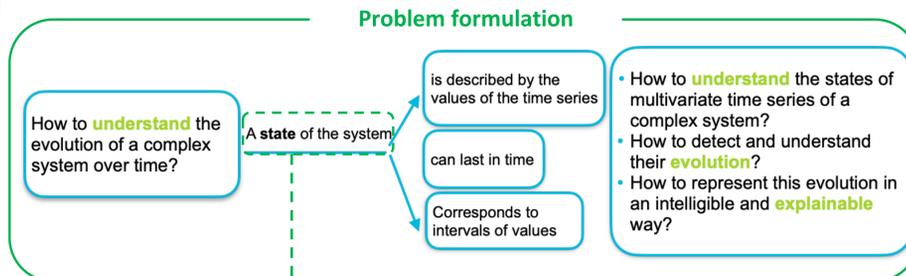
Introduction & industrial context



Is a **complex system** composed of equipments, each one connected to several sensors which return a value at given time

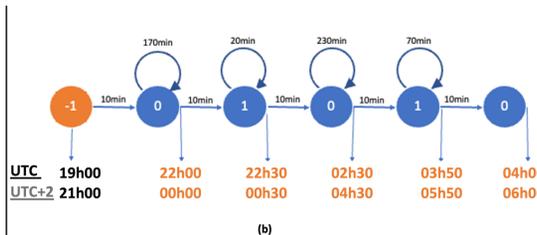
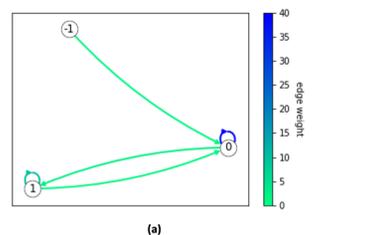
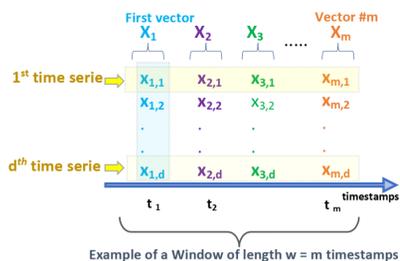
The study of a **complex system** composed of **multivariate time series**

- unlabeled
- with irregular & non-deterministic behavior
- temporal dynamics

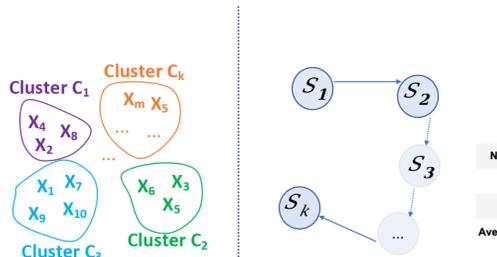
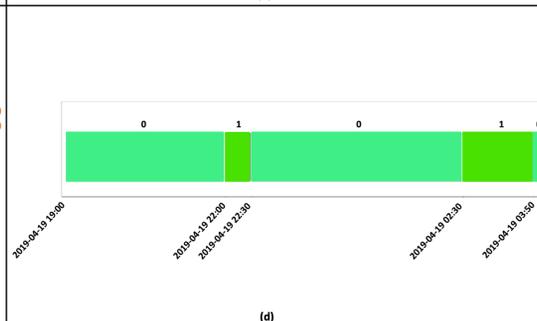


XR-CSB method: EXplainable Representation of Complex System Behavior

A 3-step methodology:



| | 170min | 20min | 230min | 70min |
|-----------------------|---------------|----------|-----------|-----------|
| UTC 19h00 UTC+2 21h00 | 0 | 1 | 0 | 1 |
| Number of records | 18 | 3 | 24 | 8 |
| Average speed | -3.905089e-04 | 0.001163 | 0.010555 | 0.000101 |
| Average Velocity | 8.657702e-04 | 0.007734 | 0.001904 | -0.009200 |
| Average acceleration | 8.174802e-07 | 0.000005 | -0.000101 | |



Originalities

1) **Vertical clustering**: independent of the size of time series ==> complexity control

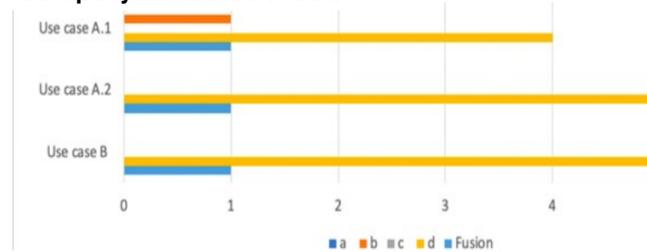
2) **Pre-modeling explainability**: explanatory metrics, speed, velocity, acceleration

3) **Visual explanation Intelligible for human experts** that can be evaluated via qualitative experiments

Experiments & Results

Dataset: Time series: 92 sensors / Time step: 10 min / Whole duration: 3 years

Company 1: Data scientists



Company 2: HCI, little experience in AI

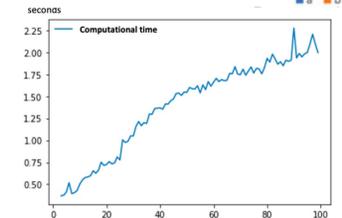
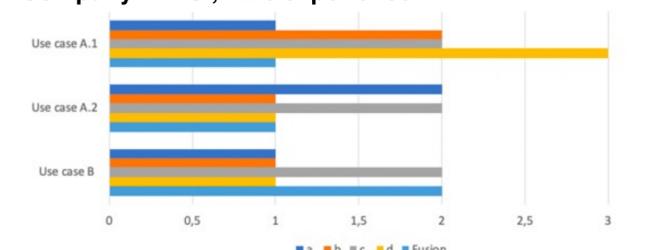


Figure 3: Execution time w.r.t. the number of clusters k : Analysis of 92 sensors over 24 hours, i.e., 144 records, for k in $\{3, \dots, 100\}$.

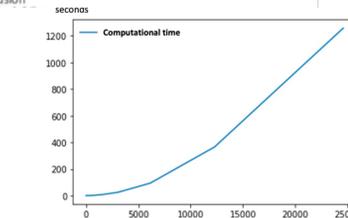


Figure 4: Execution time w.r.t the window length w : Analysis of 92 sensors, for $k = 7$ and hours h in $\{8, 16, 24, 48, 96, 192, 384, 768, 1.536, 3.072, 6.144, 12.288, 24.576\}$.

Preference for multi-modal explanations, 5-10 states

Main findings

Different perception of the acceptability of a representation according to:

- the profile of the company's experts
- the apriori knowledge of the domain
- the technical experience with the subject

- **Neophyte profiles** of a domain **prefer more information** about the complex system (Company 2)
- **Experts** familiar with the subject **seem not to need this information** there (Company 1)

Highlighting the **important trade-off between**:

- the performance of AI approaches **vs.** the relevance of the visual explanations and its intelligibility

XR-CSB method allows generating an **explainable and intelligible visual representation** of the behavior of a complex system that **interfaces with experts as well as neophytes**