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# Explaining complex system of multivariate times series behavior

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Our paper at **KDIR@IC3K 2022**  
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## Abstract

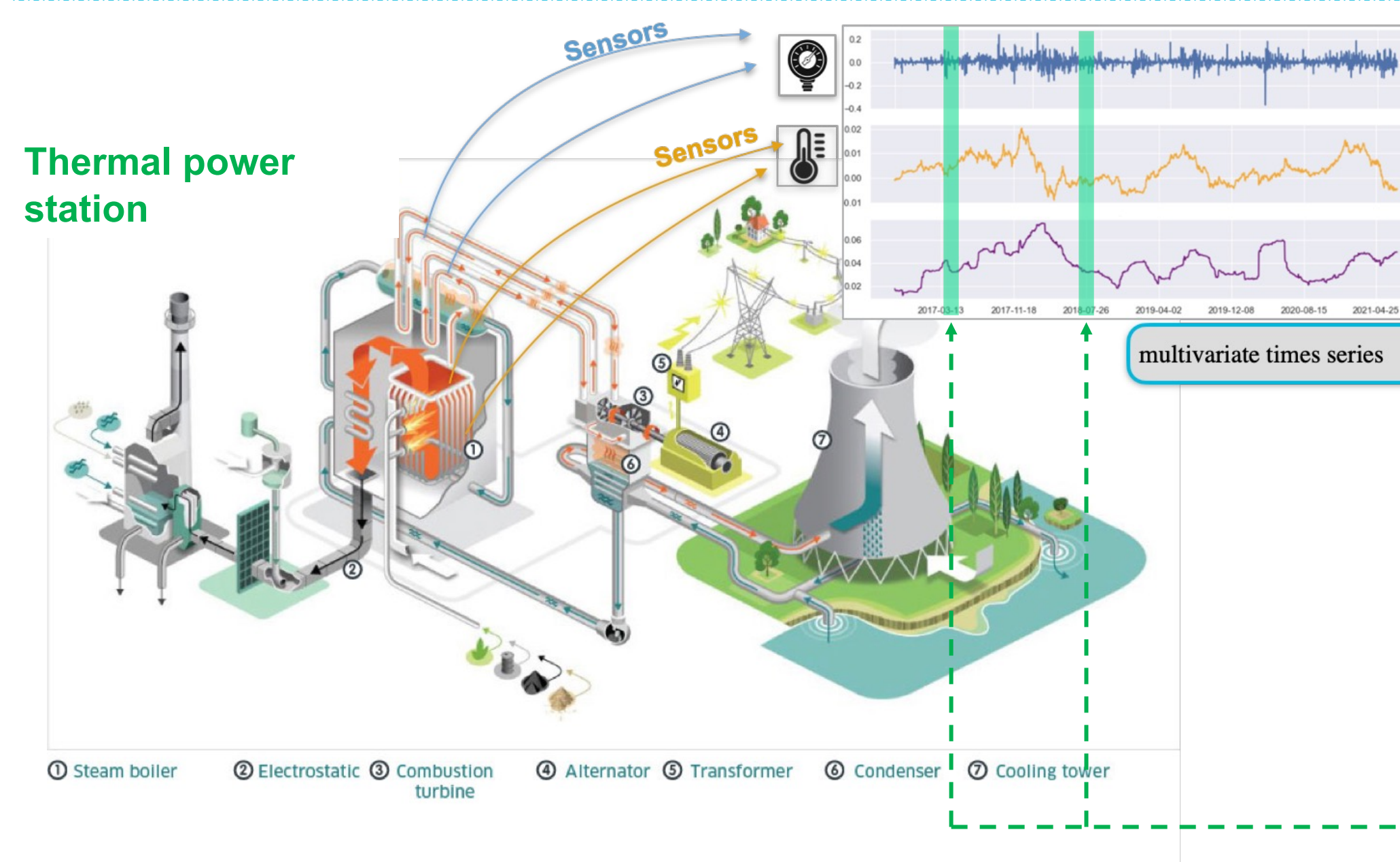
Complex systems represented by multivariate time series are ubiquitous in many applications, especially in industry. **Understanding a complex system, its states and their evolution over time is a challenging task.** This is due to the permanent change of contextual events internal and external to the 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.

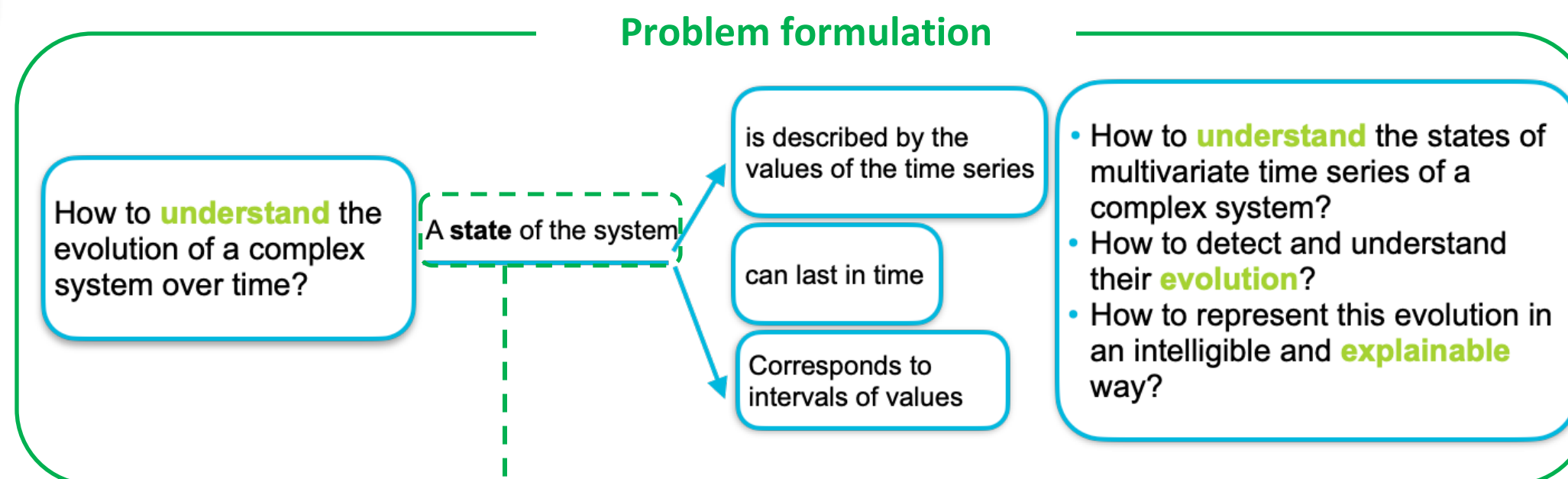
## Introduction & industrial context



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

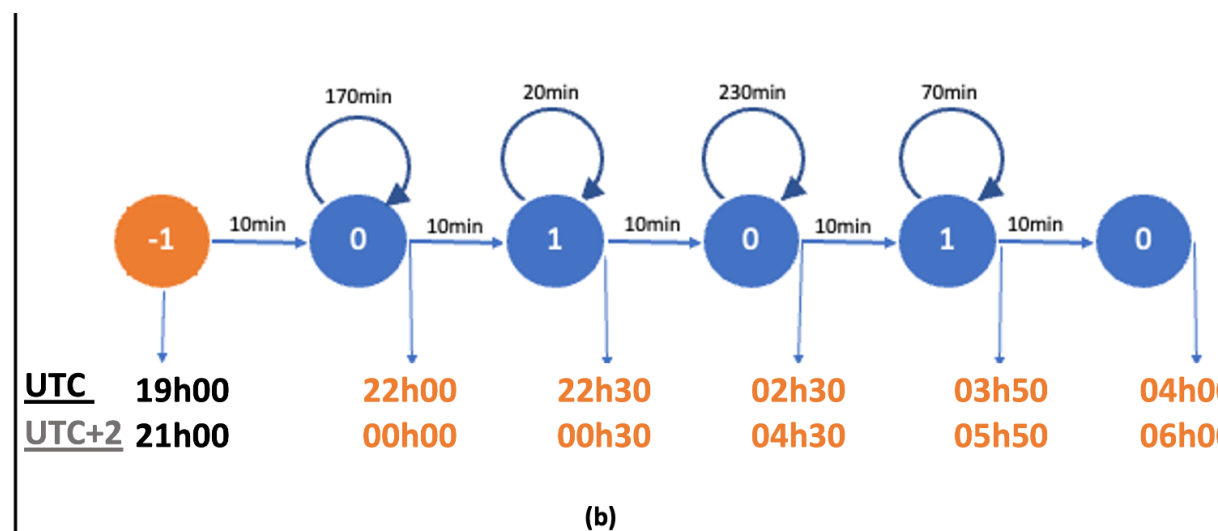
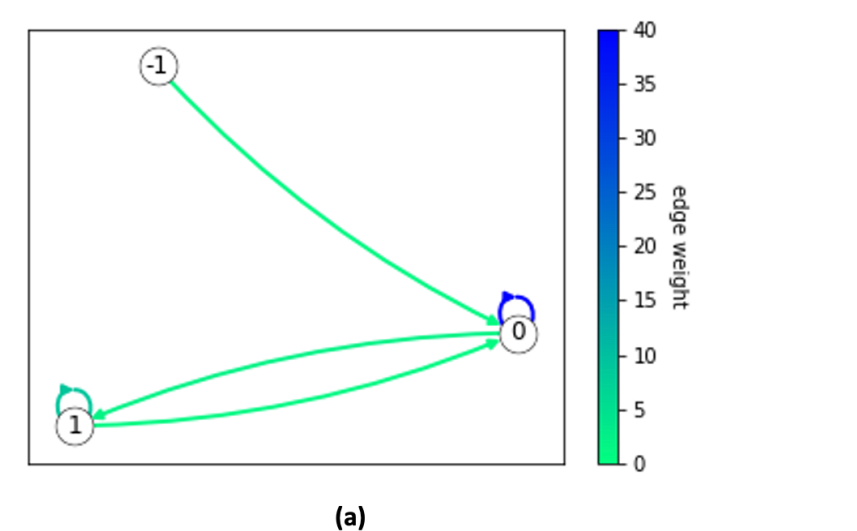
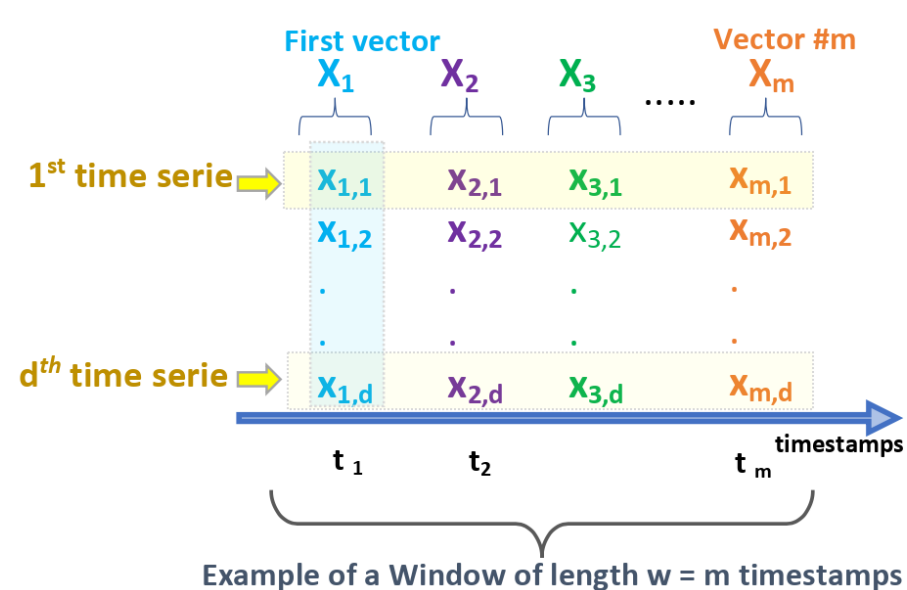
The study of a **complex system** composed of **multivariate time series**

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

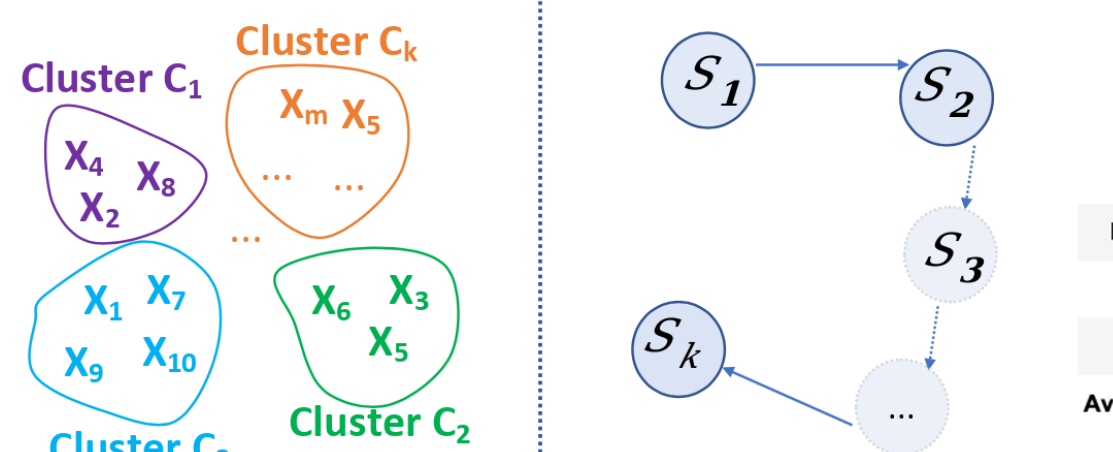
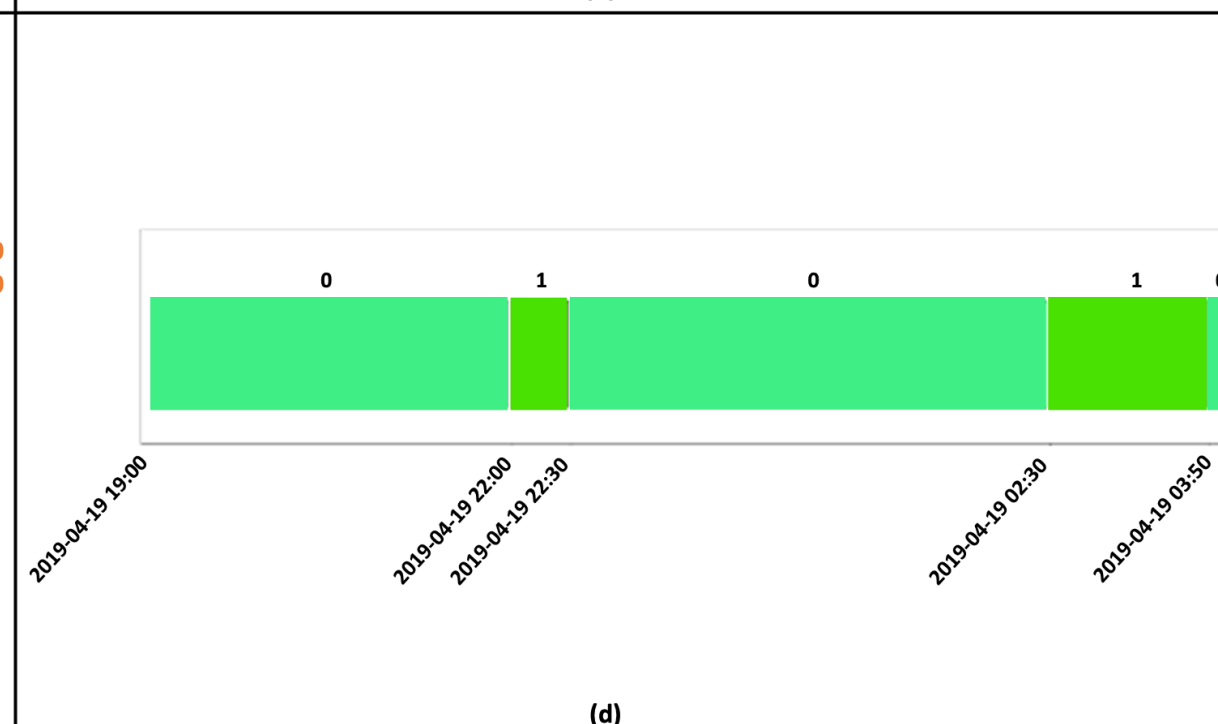


## XR-CSB method: EXplainable Representation of Complex System Behavior

A 3-step methodology:



	170min	20min	230min	70min
UTC 19h00	0	1	0	1
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

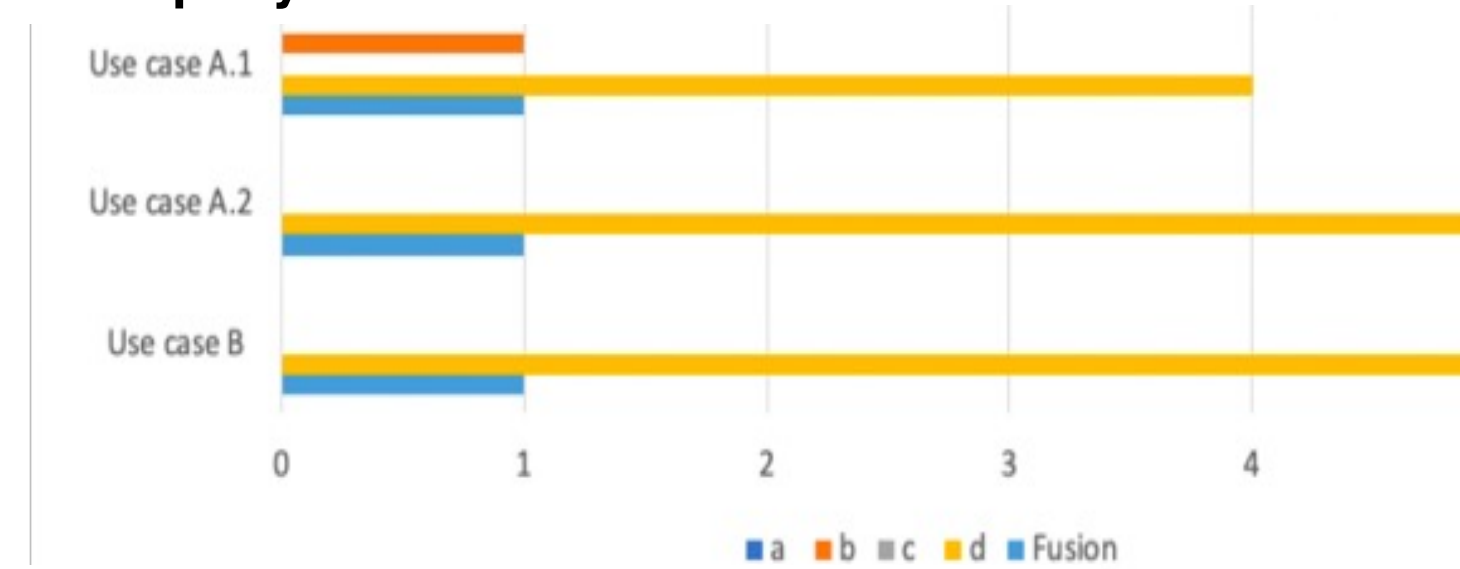
2) **Pre-modeling explainability**: explanatory metrics, speed, velocity, acceleration

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

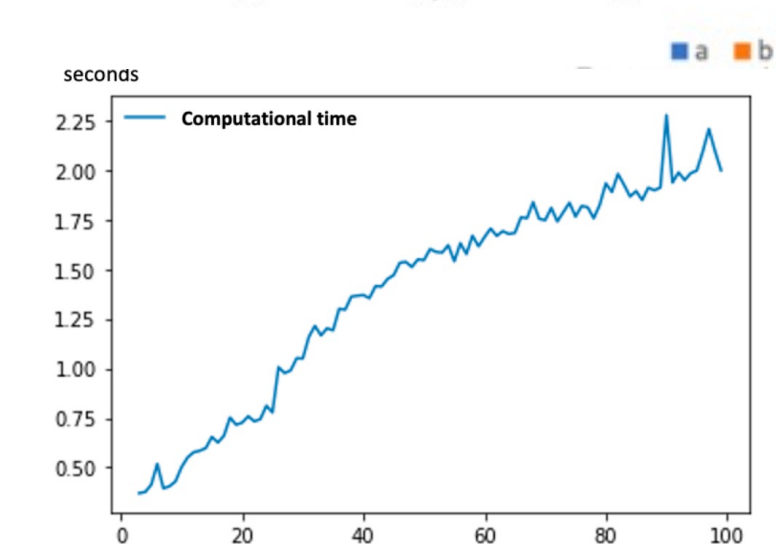
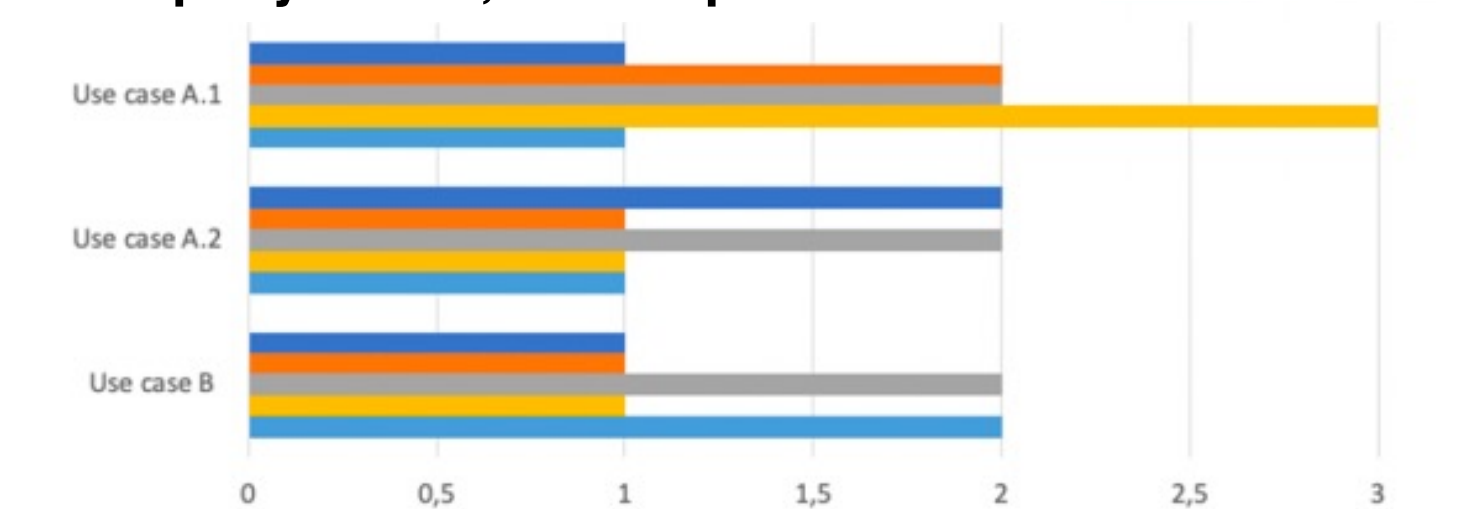


Figure 3: Execution time w.r.t. the number of clusters  $k$ : Analysis of 92 sensors over 24 hours, i.e., 144 records, for  $k$  in  $\{3, \dots, 100\}$ .

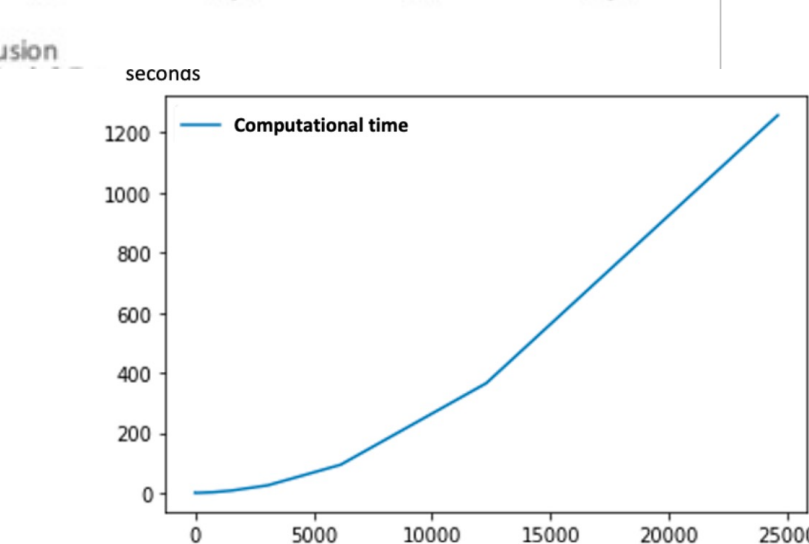


Figure 4: Execution time w.r.t the window length  $w$ : Analysis of 92 sensors, for  $k = 7$  and hours  $h$  in  $\{8, 16, 24, 48, 96, 192, 384, 768, 1.536, 3.072, 6.144, 12.288, 24.576\}$ .

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**