CHASING ABNORMALITIES ON TIME SERIES FOR PREDICTIVE MAINTENANCE AND ADVANCED PROCESS CONTROL

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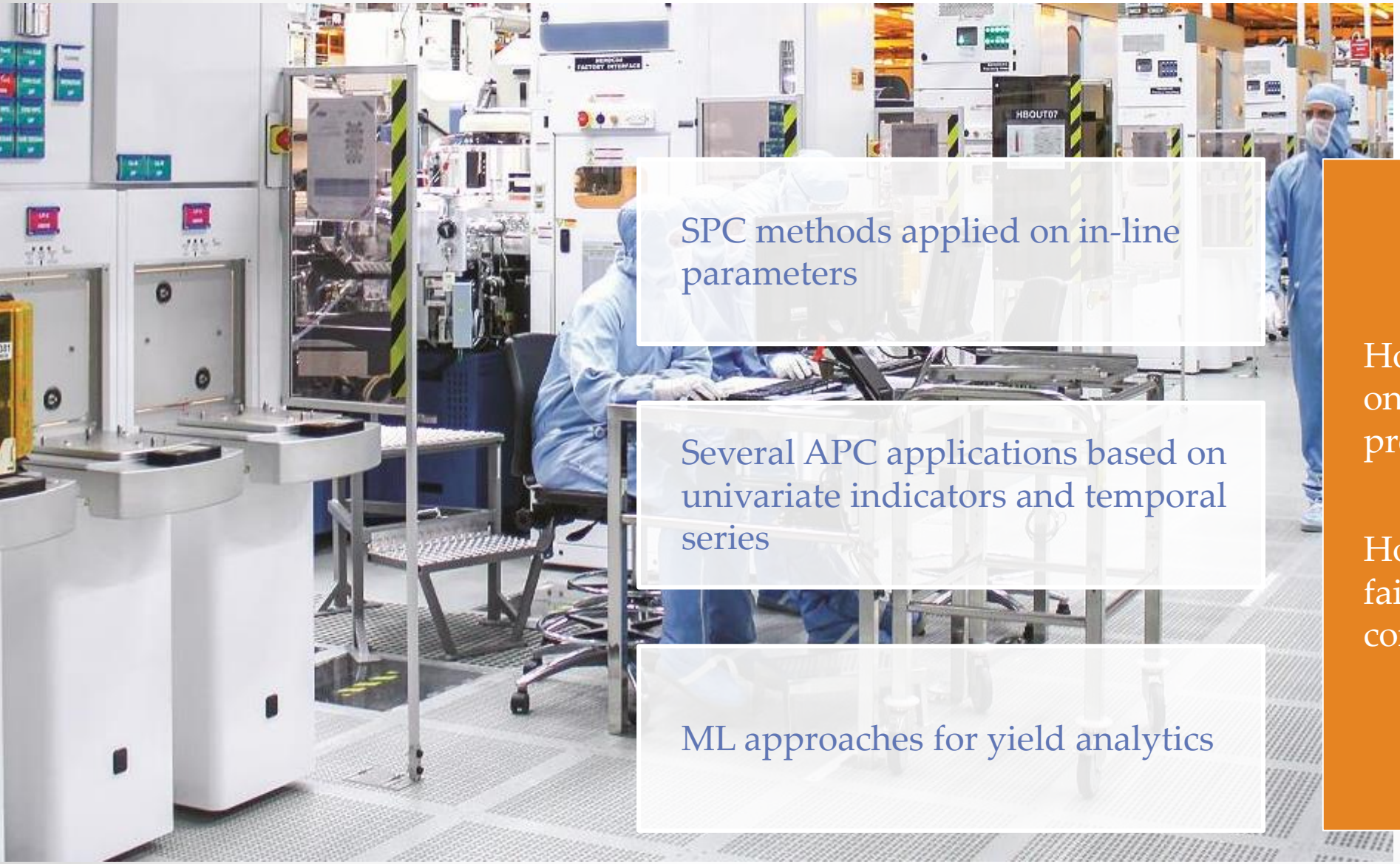
Context: equipment control and quality control



SPC methods applied on in-line parameters

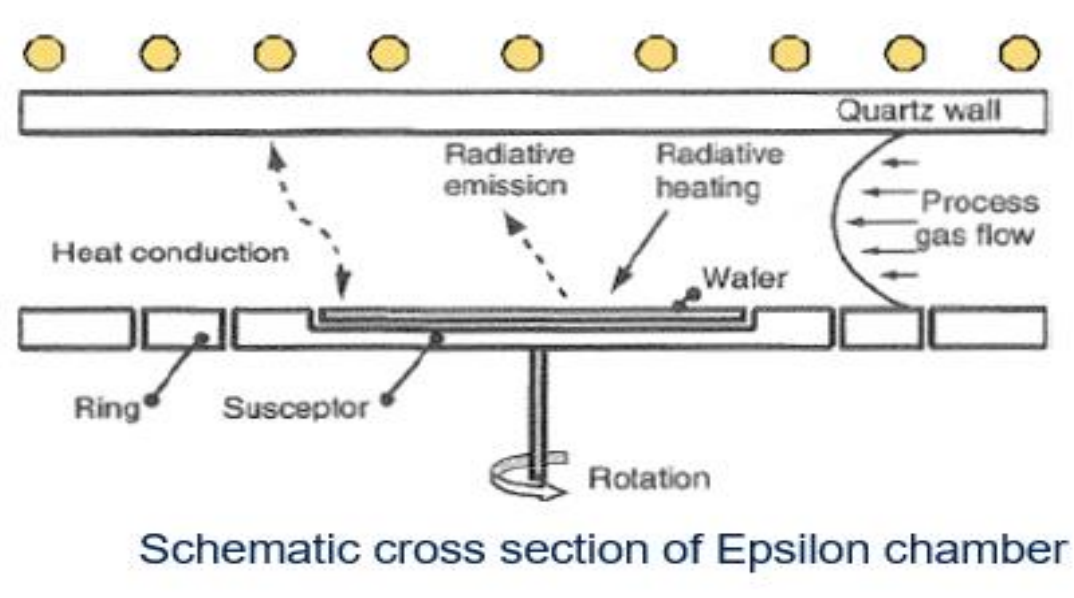
Several APC applications based on univariate indicators and temporal series

ML approaches for yield analytics

How to improve accuracy on equipment failures predictions?

How to catch drifts and failures on closed loop control systems?

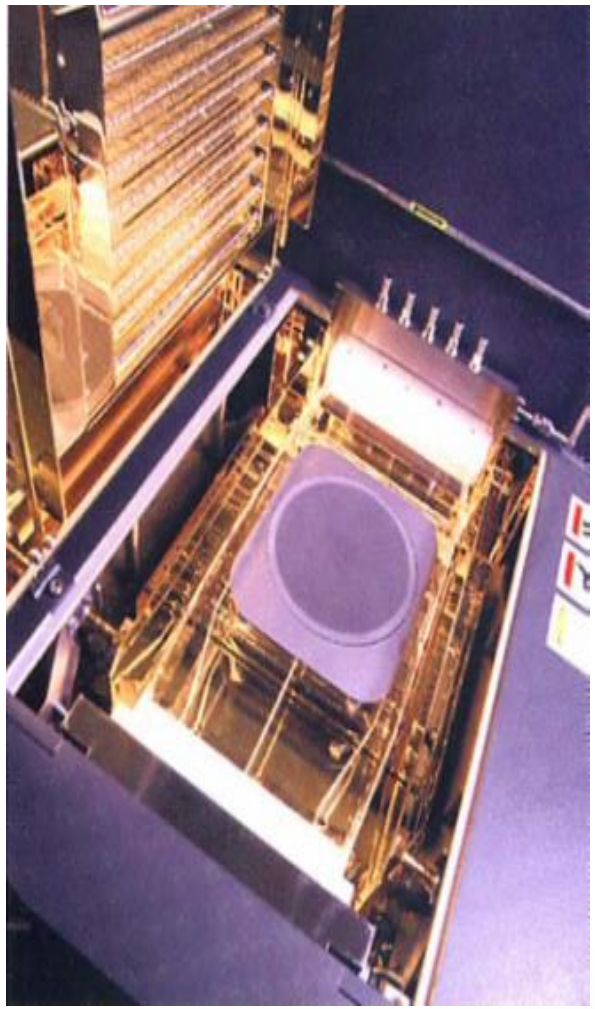
Use case: thermal drift on epitaxy reactor



Schematic cross section of Epsilon chamber

Epitaxy Growth: CVD Deposition

The grown material is crystalline and reproducing the crystal arrangement of the substrate underneath.

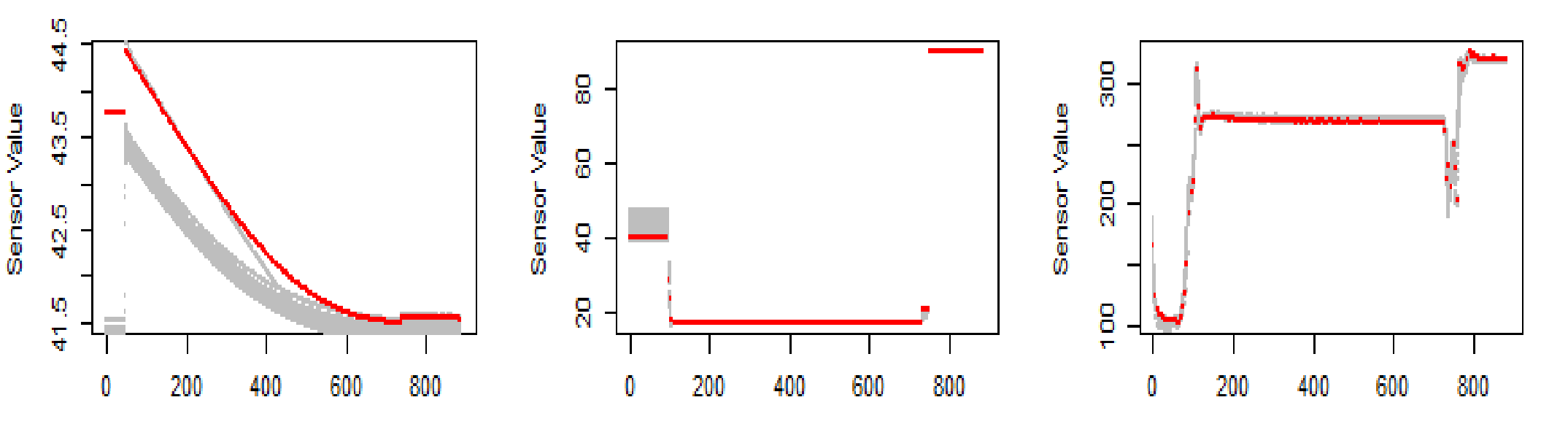


Thermal drift

Heating systems based on closed loop approach guarantee the best compromise to reach temperature setpoint.

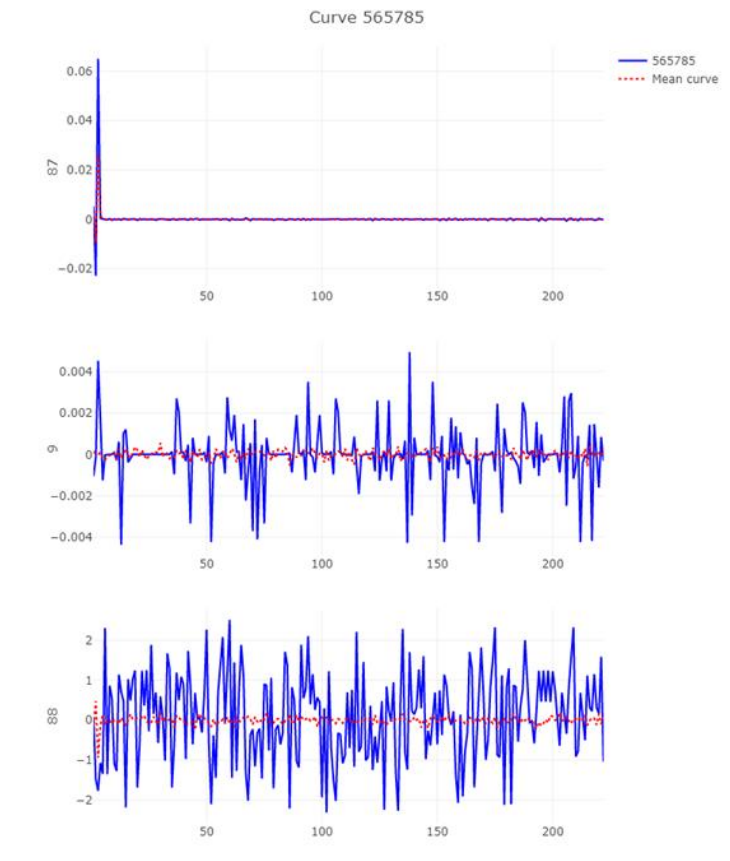
Power applied on lamps banks is varying and modulating, it is not trivial to distinguish regular trends from anomalous ones.

What is functional data?

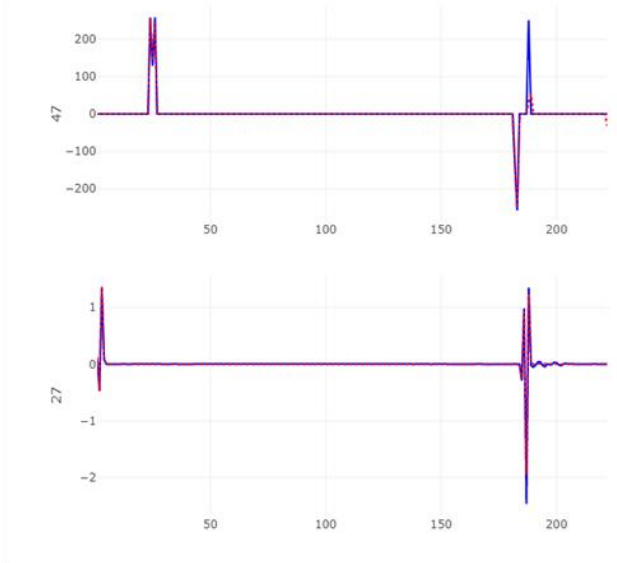


Functional data are curves, usually temporal curves also called time series, above is an example of 3 sensors

CHAM: processing data – step 1



3 sensors with abnormal time series (the blue curves)



The innovation: time series are transformed in a real valued number, a “distance”

For each sensor

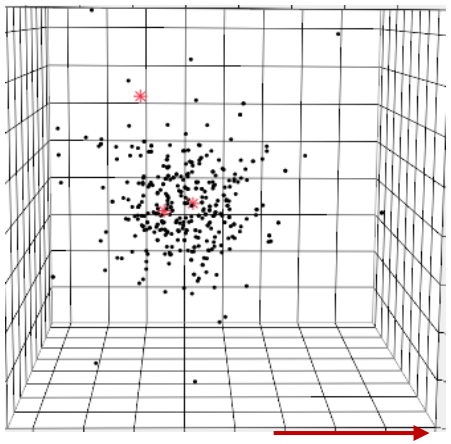
1- CHAM computes a « standard curve » based on the data collected from all the runs

2- CHAM assigns to each run a value that reflects the 'distance' between the actual curve of that run and the standard curve

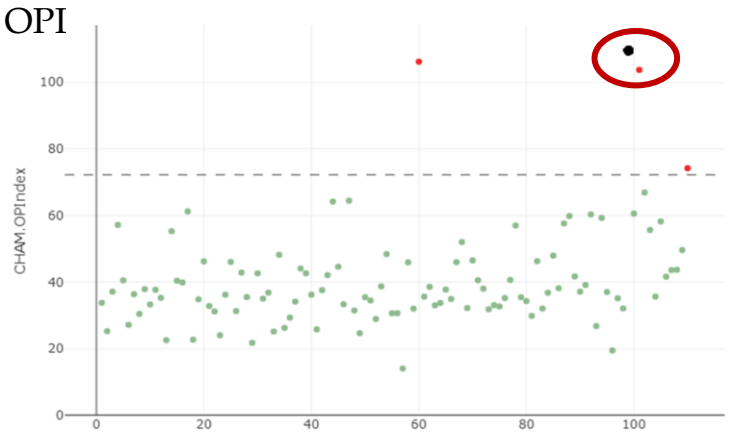
Patent Pending

CHAM: processing data – step 2

Projection Pursuit



Complex p-dimension space (here in dimension 3)



CHAM at work: the red circle reveals small signal on 2 runs (leakage detected in advance)

Result for each unit (sensor) are projected from *a p-dimensional space to a 1-dimensional space:* $P(x_i)$ *is the Optimal Projection Index*

CHAM algorithm summary

- Following steps are performed, unsupervised method

  0. Imputation of missing data & preprocessing
  1. Curve modeling and distance calculations
  2. Projection Pursuit for abnormal curves detection
  3. OPI (Optimal Projection Index) calculation from steps 1&2
  4. Outlier detection on the OPI

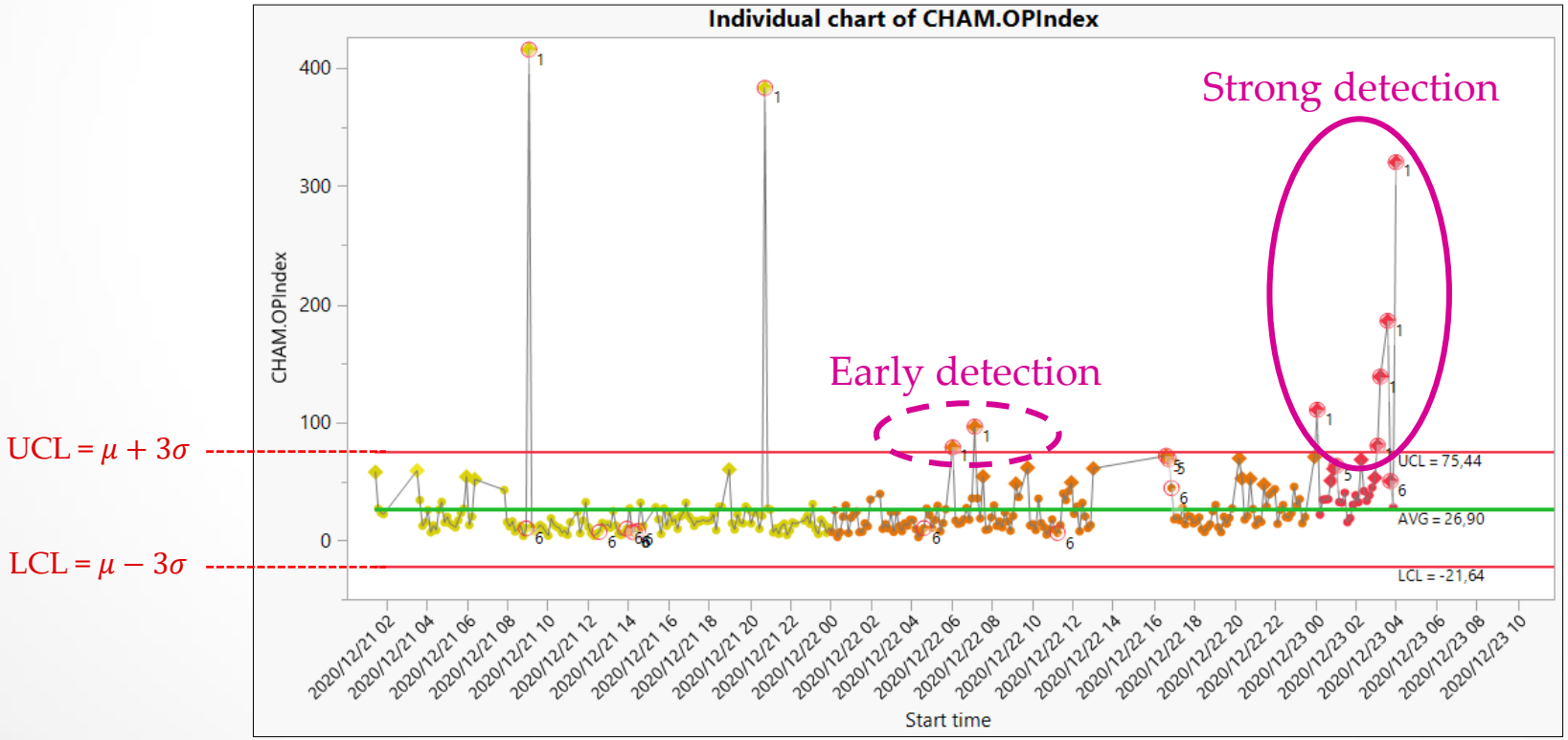
- Reminder
  - CHAM step 1 is a fully new method, patent pending
  - CHAM step 2 is different from FPCA (different goal) and from the Mahalanobis distance or Hoteling T^2

  (these methods work poorly when the parameters are correlated and numerous, this is often the case with sensors)

Epitaxy use case - OPI control chart

- CHAM runs on December 2020 data (full month)
- Among the 2326 observations 27 outliers are identified by CHAM, i.e., **1.16%** of the observations
- Occurrence of the failure : 23rd of December 2020, around 4 am

- <u>OPI Control chart</u> : 2020/12/21 to 2020/12/23 (1 day prior failure)



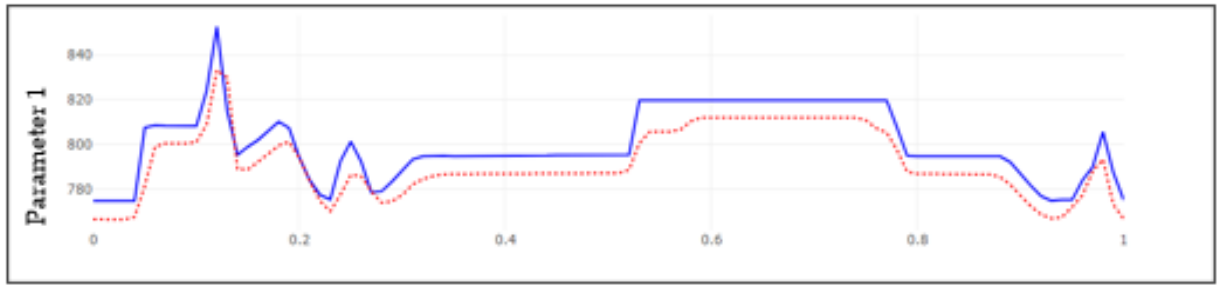
Control chart representation highlights the irregular patterns detected by CHAM's OPI near the failure occurrence

Epitaxy use case - contributors

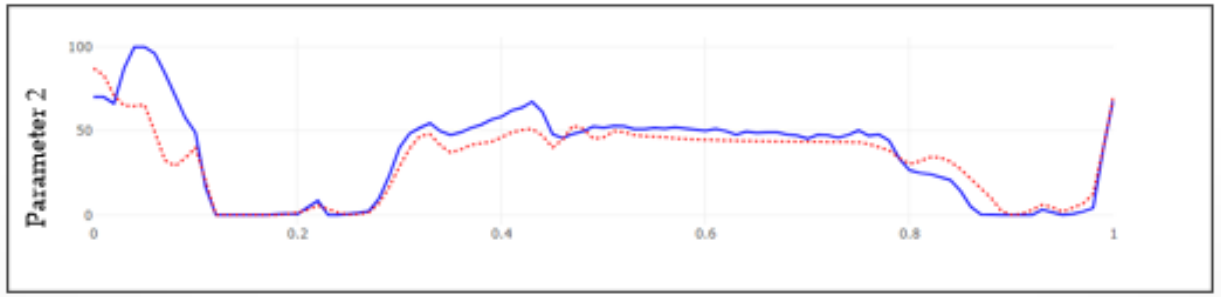
- Contributors are the parameters **most involved in the OPI out of control**

- **Example of 2 contributors**: associated to early/strong detection patterns

Parameter n°1



Parameter n°2

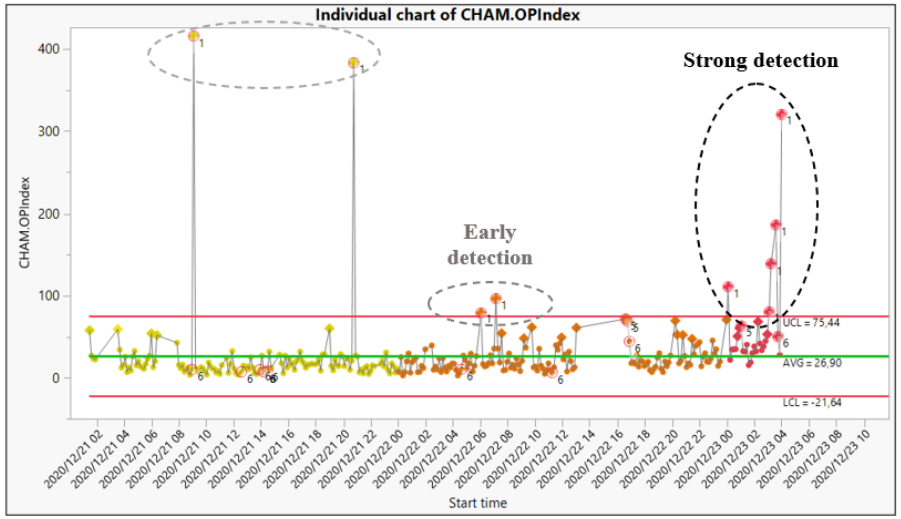


Mean curve (all observations)

Observation with out-of-control OPI

Conclusion and opportunities

- Good results on epitaxy data: failure caught in advance
- CHAM is being deployed in pilot production at ST Catania



Acknowledgments

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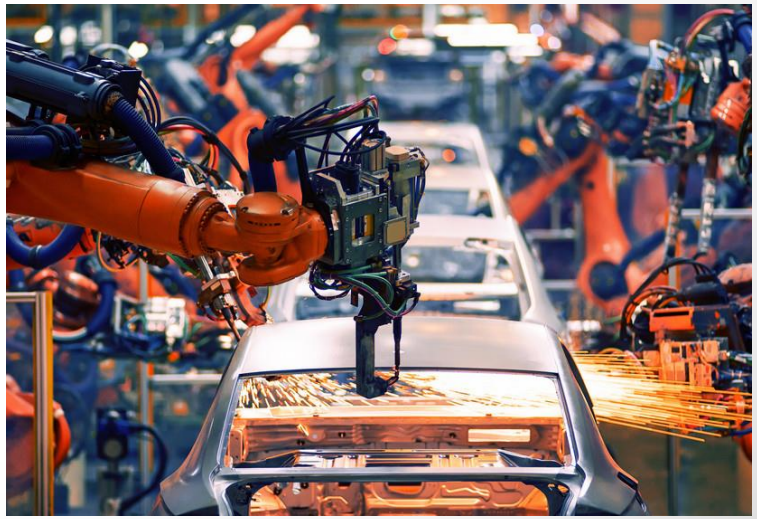
Opportunities for cross-fertilization between different industries

- During MADEin4 project CHAM was also used in automotive industry, on engine quality control tests
- Lesson learnt:
  - The number of sensors was clearly lower
  - **The alignment method developed by ippon for semiconductor is been reused for automotive engine control on time series**
  - CHAM is also efficient on quality control time series
  - Statistics is universal!



QUESTIONS?