Openlab Workshop on Data Analytics

16th of November 2012

Axel Voitier – CERN EN-ICE

# INDUSTRIAL CONTROLS DATA ANALYTICS USE CASES

Outline

- Industrial Control Systems at CERN

- Data Sources for Analysis

- Possible Use of Data Analytics:
  - Online Monitoring
  - Fault Diagnosis
  - Engineering Design

- Where to go with our tons of data?

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE

Typical Industrial Control System
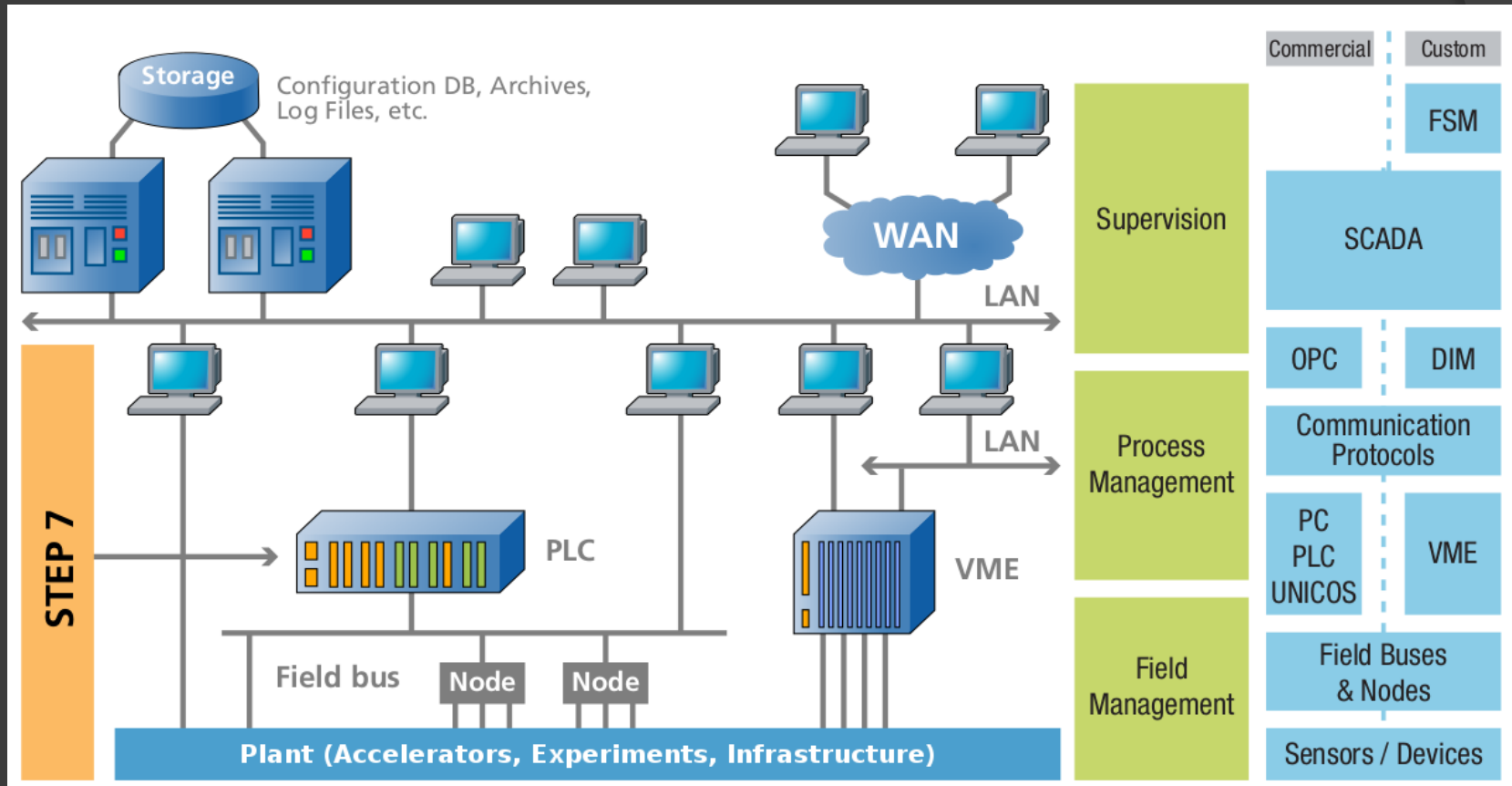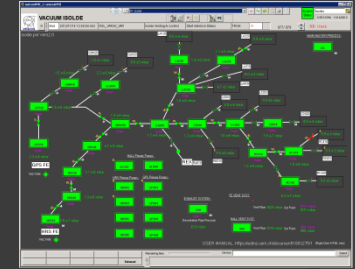
Technologies

- ◉ **Supervision layer**
  - Siemens WinCC Open Architecture
  - National Instrument LabView

- ◉ **Control layer**
  - Programmable Logic Controllers
  - Front End Computers
  - VME modules, PXI controllers, etc.

- ◉ **Field layer**
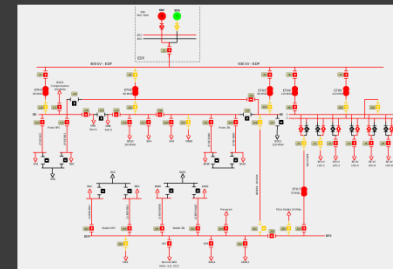 - Sensors, devices
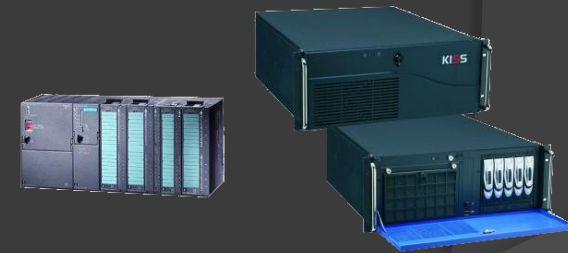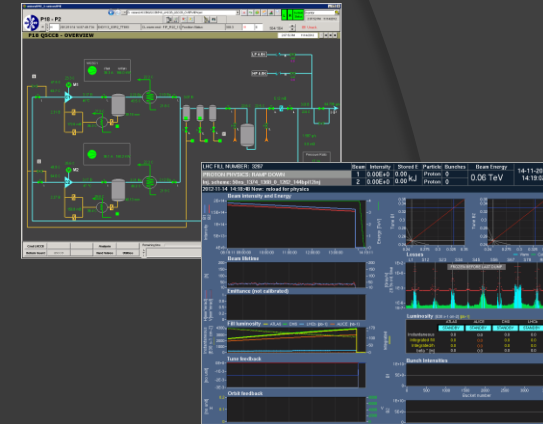
Some examples

- ◉ Accelerators
  - Cryogenics
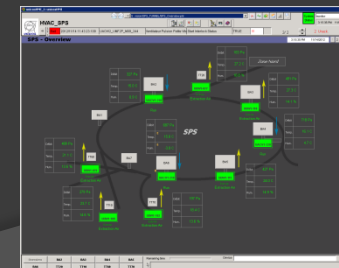 - Vacuum
  - Machine Protection

- ◉ Experiments
  - Detector Control
  - Detector Safety
  - Gas

- ◉ Technical Infrastructure
  - Cooling and Ventilation
  - Electricity

Particularities of Control Systems

- They are stables most of the time.
  - Relatively few incidents to learn from.

- But a single system failure can lead to a complete stop of the accelerator(s).
  - Beam dump!
  - Unavailability time (repair + recovering).
  - => High global cost.

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE

Data sources for analysis

- Online values
  - Single value, instantaneous.

- Archives
  - LHC Logging + PVSS archives.
  - +100 Tbytes, extensible.
  - Data and alarms.

- Log files
  - Almost never used.

- Configuration data

Industrial Controls Data Analytics U
Axel Voitier - CERN EN-ICE

Use case 1: Online Monitoring

Detect issues and inform operators before they affect the process under control.

Possible applications:

- Control systems health.
- Electrical power quality of service.
- Looking for heat in superconducting magnets.
- Oscillation of cryogenic valves.
- Discharge of superconducting magnets heaters.

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE

Inputs/Outputs

- **Inputs**
  - Operating system information.
  - Network load.
  - PLCs status information.
  - Process measurements.
  - Layout database.
  - Log messages.
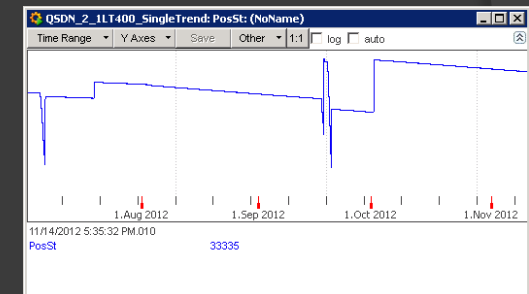
- **Outputs**
  - Alerts, sent to our stand by service by SMS.
 - Periodic summary reports.

Type of analysis

- Analysis Processes
  - Thresholds learning.
  - Correlations.
  - Classifications.
  - Formalisation of temporal relations (eg. Markov chain, Wavelet, FFT).
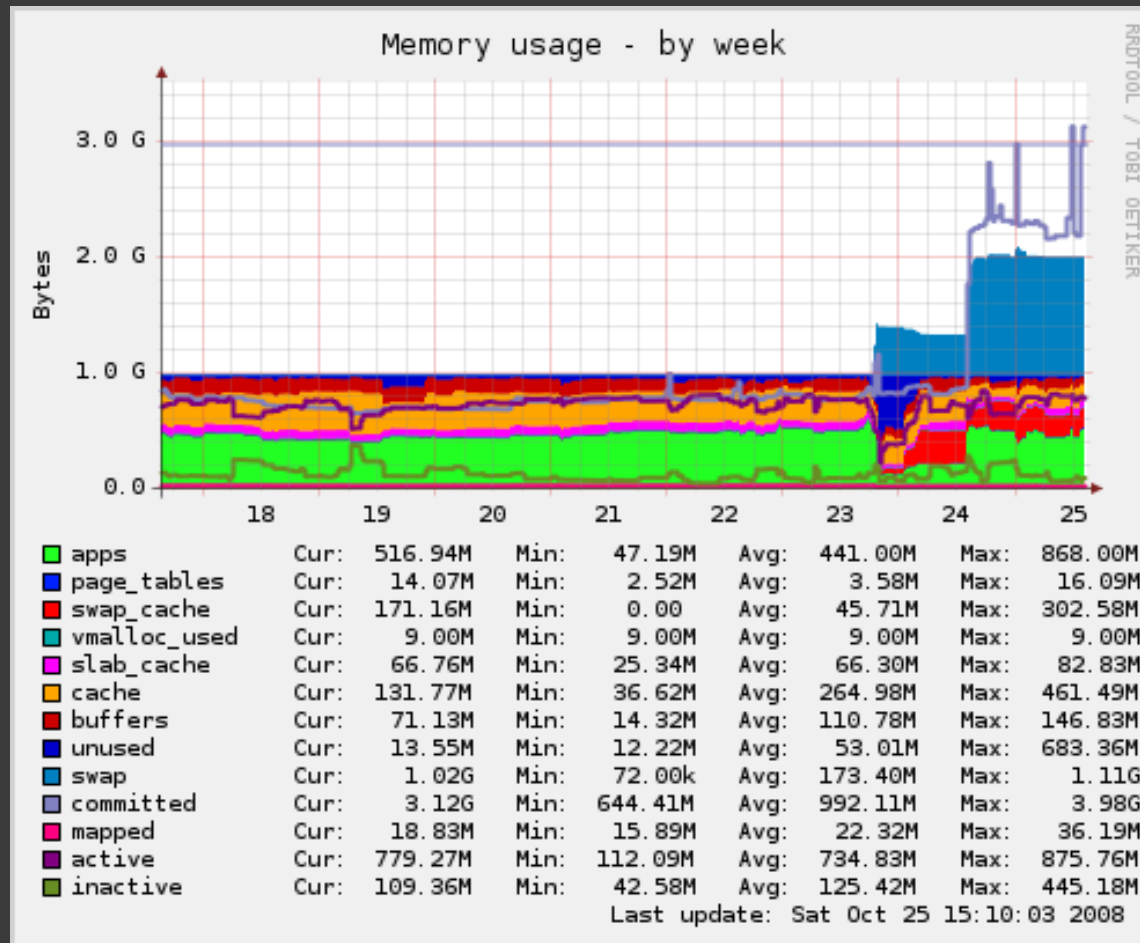 - Pattern recognitions.

- Time span:
  - Learning over relatively long periods.
  - Detection periods: "immediate", 1 week, 1 month, 1 year.

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE

Example 1: Hard drive failure
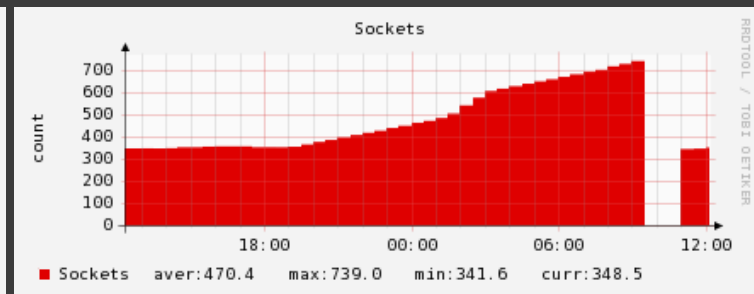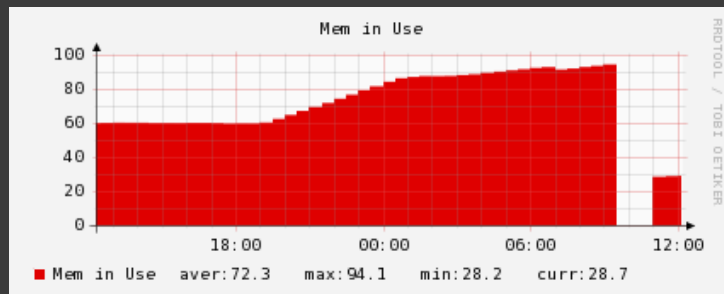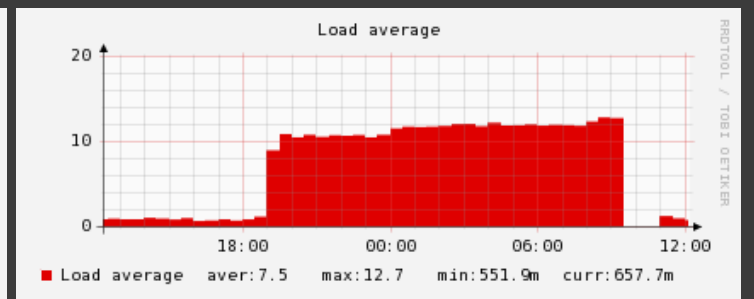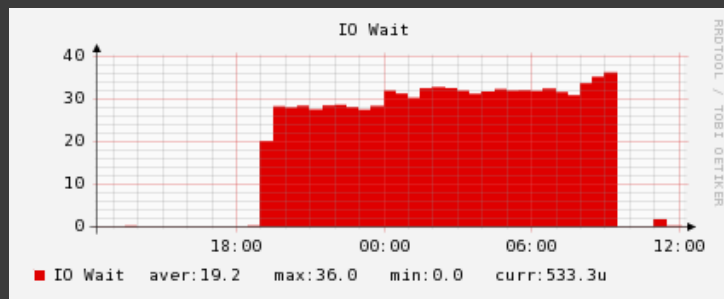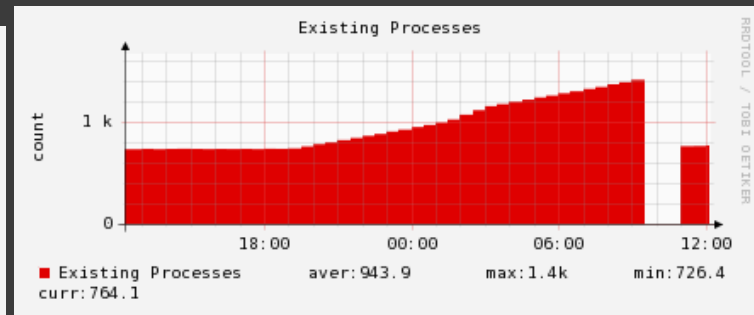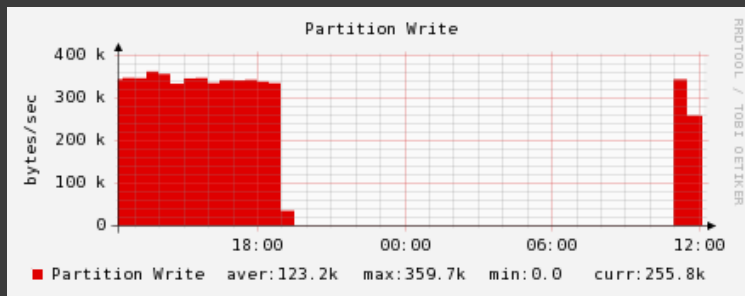
Example 2: Memory disturbance

Industrial Controls Data Analytics Use Cases
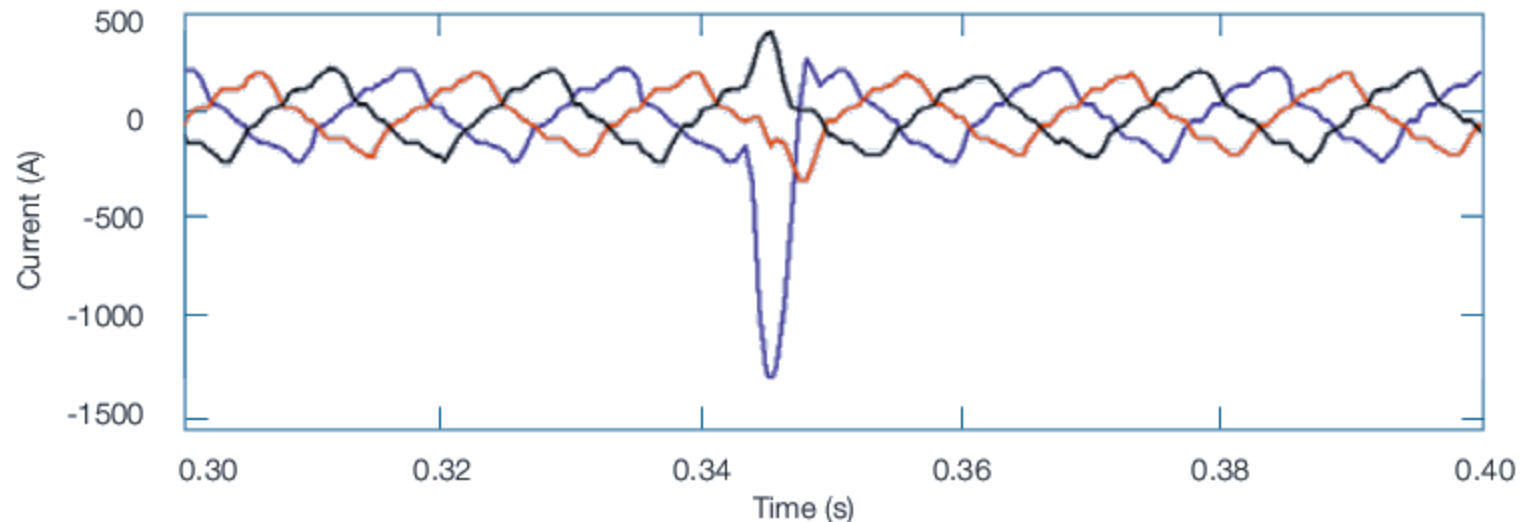Axel Voitier - CERN EN-ICE

Example 3: Incipient fault on electrical network

Example recording of an incipient failure. This was a self-clearing fault that did not result in any immediate outage.


Subsequent monitoring recorded 140 additional cases of similar incipient failures until the catastrophic failure nine months later that blew a 65A fuse

Mirrasoul et Al., "Real-time automated distribution event detection and notification for grid control", ABB Review 3/2009, p.38-44

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE

Current developments

- Exploring machine learning techniques for control systems health monitoring.
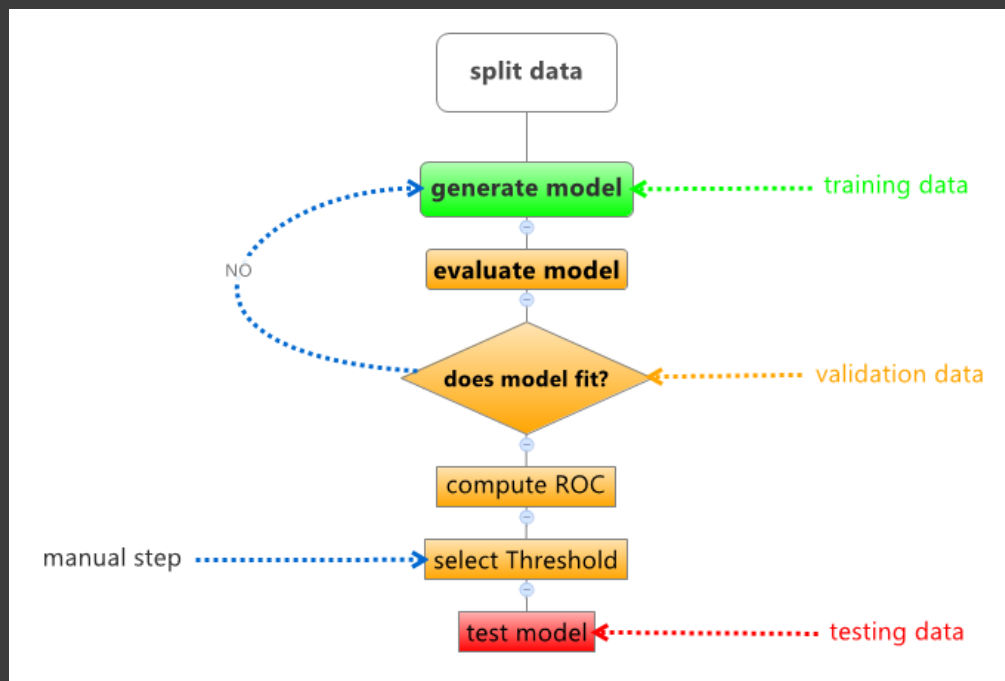
Adrian Vlad LEP – CERN EN-ICE

Use case 2: Fault Diagnosis

Helping operators to find the root event in an avalanche of alarms.

Complex system → Break down → Threshold crossing → First alarm → Interlock → Shutdown → New alarms
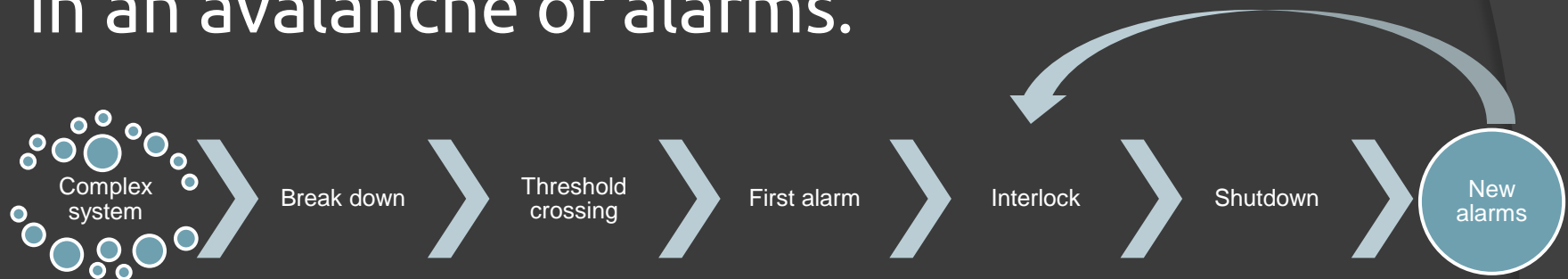
Possible applications:

- Analysis of electrical power cuts.
- Cryogenic system breakdowns.

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE

Inputs/Outputs

- ⊙ Inputs
  - Hundreds of Analog/Digital Inputs/Outputs.
  - Event list.
  - Alarm list.

- ⊙ Outputs
  - Incident report for the operator.
  - An identified/classified result.

Type of analysis

- Analysis processes
  - Pattern classification.
  - Model based methods (process simulation).
  - Knowledge based methods (interlocks are known).

- Time span
  - An avalanche of alarm is short. But…
  - … The root cause can happen hours/days before.

Current developments

- Research on cryogenic systems breakdown diagnostic
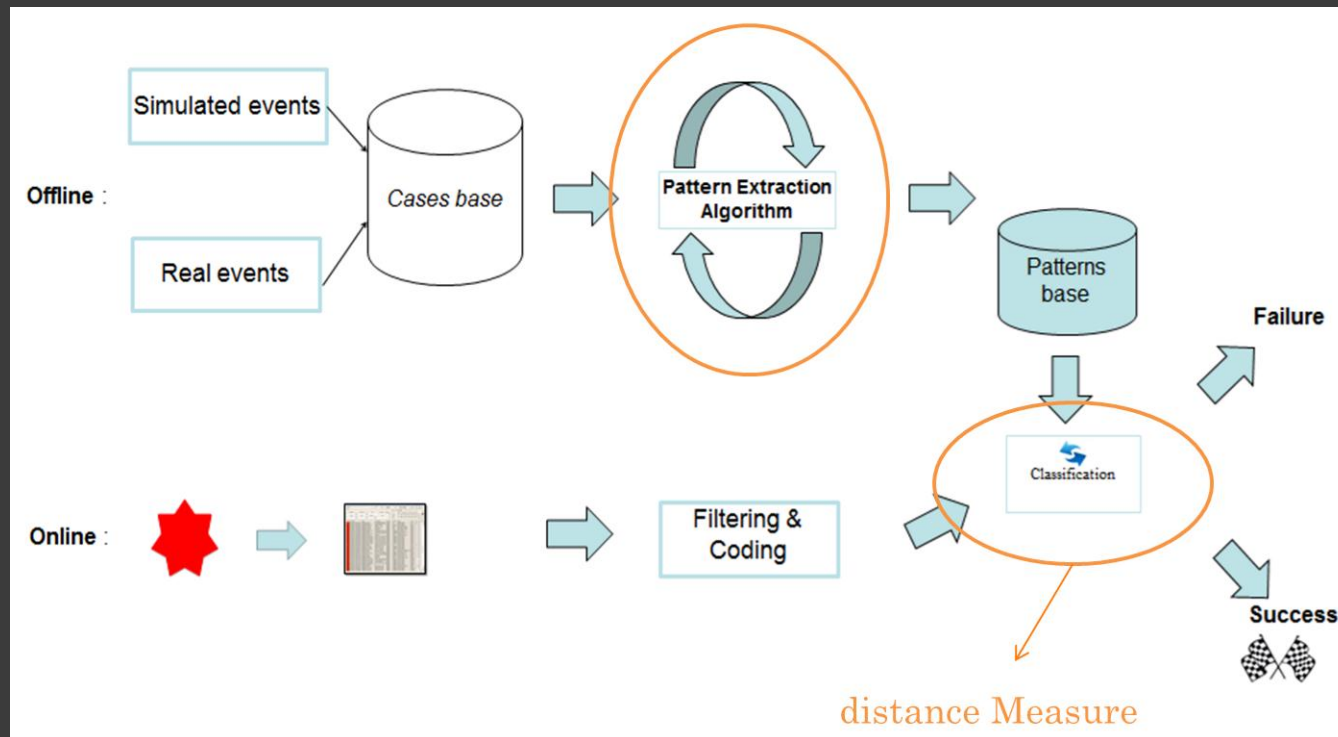
Nabil Bouchair – CERN EN-ICE

Use case 3: Engineering design

Analyse historical data to draw conclusions about the behaviour of a system.

Possible applications:

- Electrical consumption forecast.
- Predictive maintenance of control systems elements.
- Vibration analysis.

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE

Inputs/Outputs

- Inputs
  - Any kind of process data.

- Outputs
  - Detailed status reports.
  - Previsions.

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE

Type of analysis

- Analysis processes
  - Multivariate interpolations.
  - Correlations.
  - Inferences based on knowledge or model.
  - Unsupervised classifications.

- Time span
  - As long as the system has existed and will exist.

Where to go with our tons of data?

- We have a lot of data!
  - Very few are used though.
  - But we have some ideas…

- Currently doing preliminary studies
  - Prospect and researches.
  - Many techniques to explore.

- Challenges ahead
  - Suitability of state of the art techniques to our domains.
  - Integration within our tools and environment.
  - Hard to reuse a development, every use case seems unique.

Industrial Controls Data Analytics Use Cases
Axel Voitier - CERN EN-ICE