FORMALIZING EXPERT KNOWLEDGE TO ANALYSE CERN'S CONTROL SYSTEMS

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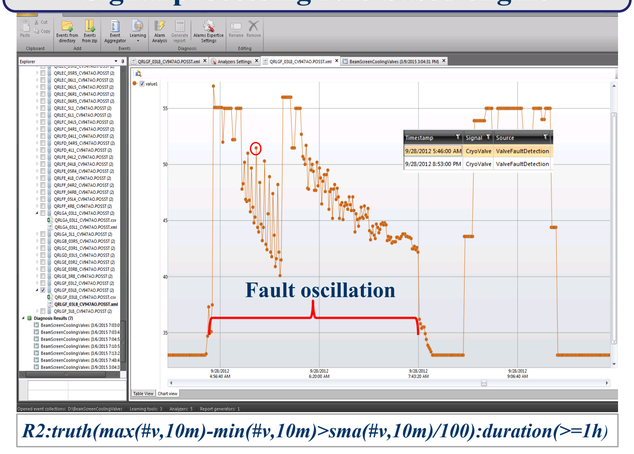
Introduction

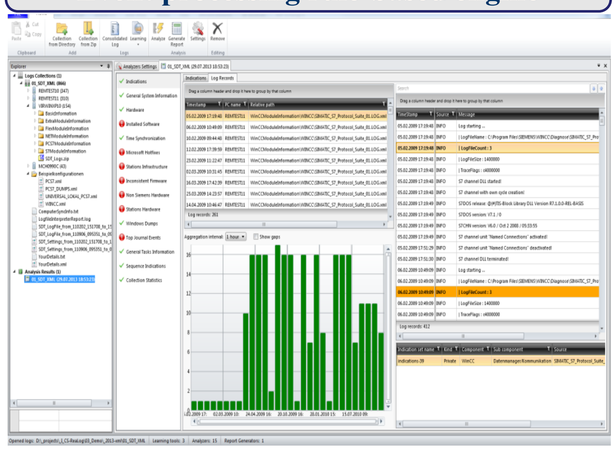
The automation infrastructure needs to reliably run the CERN's accelerator complex and its experiments; it produces a large and diverse amount of data, besides physics data. Over 600 industrial control systems with about 45 million parameters store more than 100 terabytes of data per year. At the same time, a large technical expertise in this domain is collected and formalized. The study is based on a set of use cases classified into three domains of data analytics applicable to CERN's control systems: online monitoring, fault diagnosis and engineering support. A known root-cause analysis concerning gas system alarms flooding was reproduced with Siemens' Smart Data technologies and its results were compared with a previous analysis. The new solution has been put in place as a tool supporting operators during breakdowns in a live production system. The effectiveness of this deployment suggests that these technologies can be applied to more cases with the double goal of increasing CERN's systems reliability and of reducing analysis efforts from weeks to hours. It also ensures a more consistent approach for these analyses by harvesting a central expert knowledge base available at all times.

WatchCAT Analysis Tool for Offline Analysis

Signal processing rule-based engine

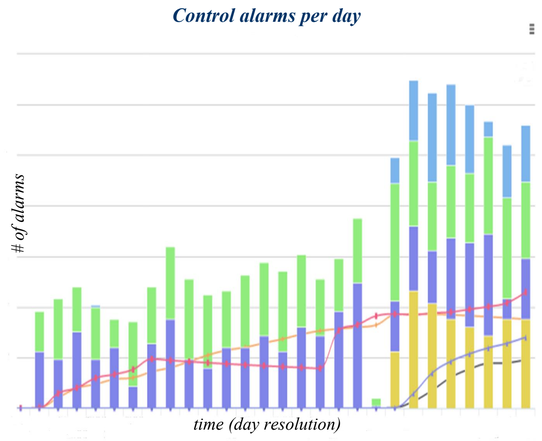


Event processing rule-based engine

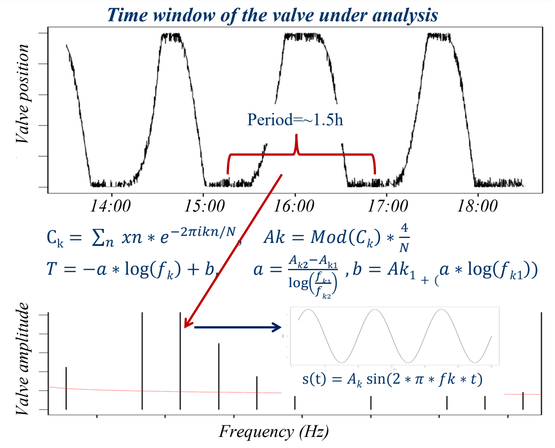


ELVis Analysis Framework for Online Analysis

Alarms threshold learning analysis



Sensors fault detection analysis



WatchCAT installation in CERN OpenStack and its data integration

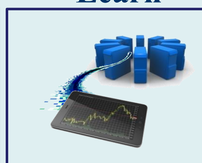
Analytics features

- Data Fusion of events & sensors
- Complex Event Processing (CEP) based on rules
- Fault Pattern Automated Learning
- Logical Reasoning for Fault Detection & Isolation
- Fault prediction based on recognizable patterns
- Signal processing
- Graph visualization

Analyze

Domain knowledge analysis for:
- Anomaly detection
- Diagnosis
- Prognostics

Learn



Provide experts with:
- Root-cause
- Gap Analysis
- Patterns Mining

Diagnose

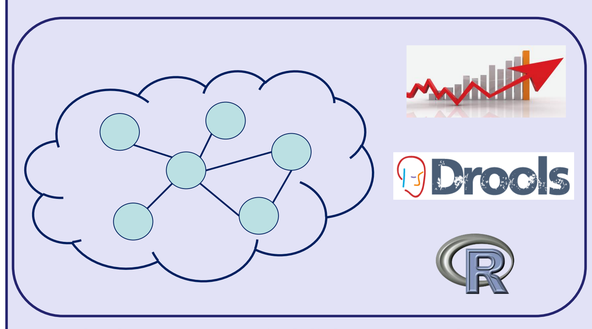
Data mining capabilities:
- Forecasts
- Trends
- Early-Warning

Offline Repository

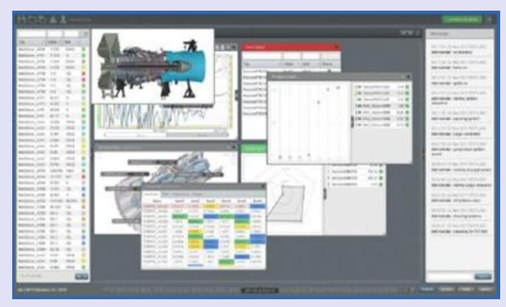
Control Data

Feedback to operators

ELVis installation in CERN OpenStack cloud and its rich web-visualization



OPC Adapter | WinCC OA Adapter | Stream Adapter



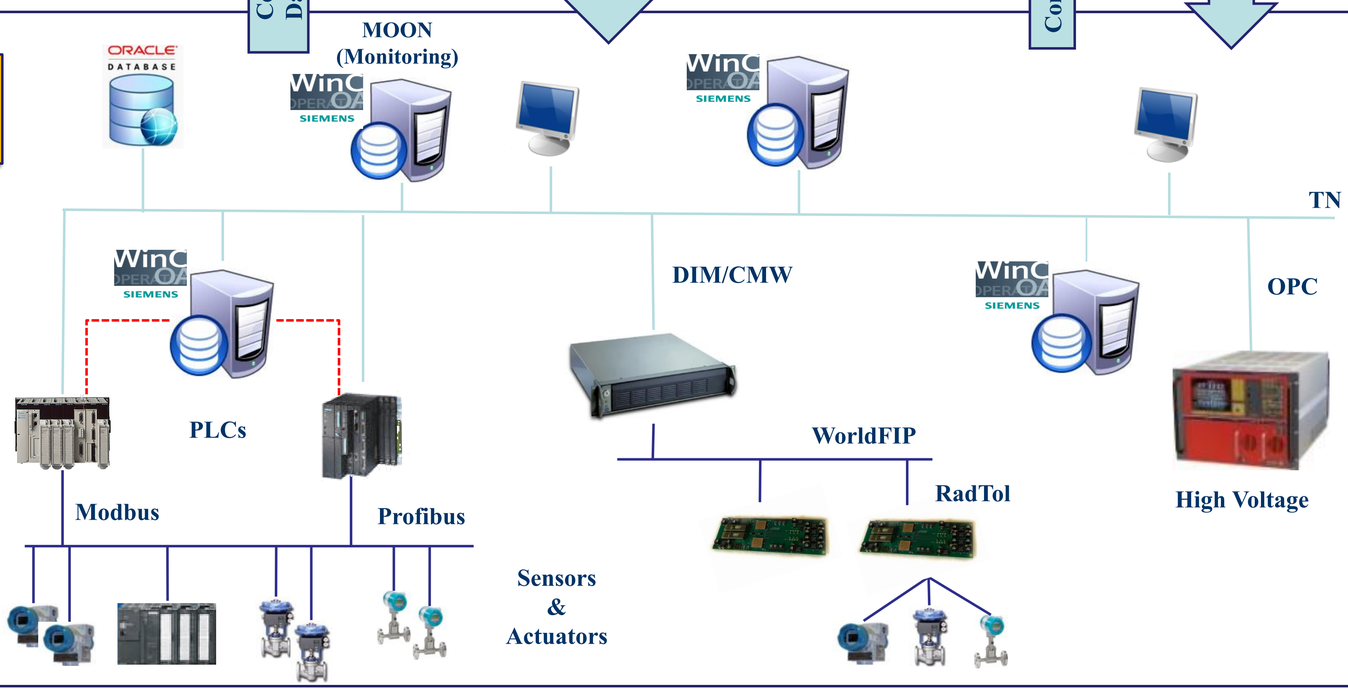
Analytics features

- Cloud-based Big Data Analytics
- Real-Time Stream Processing at customizable sampling rates
- High Performance Online Visualization in Rich Web-UI
- Sensor Data Validation Intelligence

Control Data Stream

Online Feedback

CERN Industrial Control Architecture



Summary Table

Industrial Control Application	WinCC OA Supervision Systems	Number of Parameters (I/Os)
ALICE	100	3 M
ATLAS	130	12 M
CMS	90	10 M
LHCb	160	10 M
Accelerators	200	10 M

CONCLUSIONS

Due to the complexity of CERN LHC industrial processes Smart Data technologies can play a fundamental role in their analysis to retrieve new insights and a better understanding of the entire control system. From an architectural standpoint, the latter is indeed, made of a multitude of different distributed control applications, which have been independently developed and updated. Our activities have focused on analyzing the industrial data generated by the control systems with the main goal of increasing the reliability and improving the monitoring level. Another important benefit coming out from the used analytical frameworks is the advanced support to diagnose issues (root-cause analysis) and even detect anomalies that could eventually be the cause of future forced outages. Once these anomalous patterns have been discovered and defined, a prediction system can help the operator to take the proper actions in time. It is also worth mentioning the operation support enhancement thanks to the better performances achieved by running the analysis in a cloud-based framework. The initial encouraging results have motivated CERN EN-ICE team to continue the data analytics activities as a part of the future working plan.

CERN | EN ENGINEERING DEPARTMENT | ICE INDUSTRIAL CONTROL