CMS CSC Expert System: towards the detector control automation

Evaldas Juska (FNAL), Valdas Rapsevicius (FNAL, Vilnius University), Karoly Banicz (FNAL) for the CMS CSC Group

The International Conference on Computing in High Energy and Nuclear Physics (CHEP) 21-25 May 2012, New York City, NY, USA

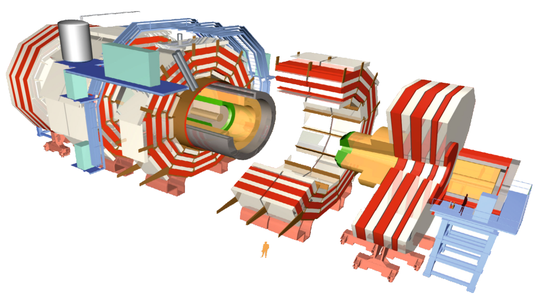
Cathode strip chambers (CSC) compose the endcap muon system of the CMS experiment at the LHC. Two years of data taking have proven that various online systems like Detector Control System (DCS), Data Quality Monitoring (DQM), Trigger, Data Acquisition (DAQ) and other specialized applications are doing their task very well. But the need for better integration between these systems is starting to emerge. Automatic and fast problem identification and resolution, tracking detector performance trend, maintenance of known problems, current and past detector status and similar tasks are still hard to handle and require a lot of efforts from many experts. Moreover, this valuable expert knowledge is not always well documented.

CSC Expert System prototype is aiming to fill in these gaps and provides a solution for online systems integration and automation. Its design is based on solid industry standards – Service Bus and Application Integration, Data Warehouse and Online analytical processing (OLAP), Complex Event Processing (CEP, i.e. Rule Engine) and ontology based Knowledge Base. CSC Expert system receives and accumulates Facts (i.e. detector status, conditions, shifter/expert actions), derives and manages Conclusions (e.g. hot device, masked chamber, weak HV segment, high radiation background), stores detector inventory – Assets (i.e. hardware, software, links) and outputs Conclusions, Facts and Assets for other applications and users. CEP engine allows experts to describe their valuable knowledge in SQL-like language and to execute it taking subsequent action in real time (e.g. sends emails, SMS'es, commands and fact requests to other applications, raise alarms).

A year of running the CSC Expert System has proven the correctness of the solution and displays its applicability in detector control automation.

CMS detector

Compact Muon Solenoid (CMS) is a high-energy physics experiment in Cessy, France, part of the Large Hadron Collider (LHC) at CERN. CMS is designed to see a wide range of particles and phenomena produced in high-energy collisions in the LHC. Detecting muons is one of CMS's most important tasks. CMS muon system consists of Muon Drift Tubes (DT), Cathode Strip Chambers (CSC) and Resistive Plate Chambers (RPC).

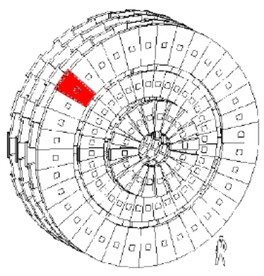


Muon End-caps

CMS EMU consists of two end-caps, 468 multilayer proportional chambers of trapezoidal shape, with cathode strips running radially and wires stretched across the strips. The cathode strips give a precise measurement of the azimuthal coordinate of the muon hits, while the anode wires give precise timing information for tagging the bunch crossing and moderate-resolution radial positions of the muon hits.

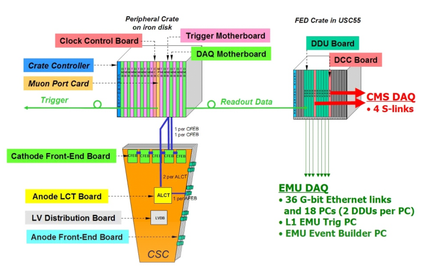
Chambers are arranged in 4 stations of concentric rings in both end-caps. Seven different types of CSCs are used in the system.

The scale of the system is huge: almost 2.32 million anode wires, 183 168 anode, and 217 728 cathode readout channels.



Cathode Strip Chamber

The CSC on-chamber electronics consists of anode front-end boards (AFEB), cathode front-end boards (CFEB), and an anode local-charged track trigger board (ALCT) that generates muon trigger primitives for the Level-1 trigger system based on wire hit information. A low-voltage distribution board (LVDB) delivers the voltages necessary for the on-chamber electronics. The raw data and the trigger information from the CFEBs and the ALCT board are sent by skewclear cables to a data acquisition motherboard (DMB) and a trigger mother board (TMB), which are located in a peripheral VME crate.



The Problem

This sophisticated detector is being controlled and monitored by many systems, i.e .Detector Control System (DCS), Data Quality Monitoring (DQM), Front-end Detector Control Manager (FED CM), Peripheral Crate (PCRATE), etc. These individual systems are highly specialized, driven by experts and are functioning well. Despite this, detector operation faces a number of problems:

- decision making requires data from many different sources,
- no single decision point, many unsupportable scripts emerge,
- historical information is not well preserved, can not be browsed and compared by non-expert,
- lots of details and crucial information about detector operation remains undocumented or is spread out in white-papers, wikis.

Solution

Create the single point of information aggregation and automated decision making for CSC. Functional requirements:

- accept/accumulate FACTS (detector status, shifter actions, etc.),
- create/close CONCLUSIONS (HV down/up, chamber masked, etc.),
- store/manage detector CONFIGURATION,
- output FACTS, CONCLUSIONS, CONFIGURATION.

Non-functional requirements include hiding complexity, reusing existing tools and techniques, efficiency and use of industry standards. It must not replace any of the existing systems, but rather efficiently use the provided data. So flexibility and easy adaptation to changing environment and requirements is an essential part of the solution.

Implementation

The system is being actively developed in the frame of CSC community since January 2010. The initial version was deployed to production on November 2010.
Key technologies:

- Platform: Java EE 6
- Application server: Glassfish 3.1
- Database: Oracle EE 11g
- Integration platform: OpenESB (a.k.a. GlassfishESB)
- Rules engine: Esper CEP
- Graph database: Neo4J
- IDE: Netbeans

Use Cases

A number of rules were implemented that give feedback to detector control system and operations team:

- HV channel trip recovery (force ON after 10 minutes)
- Multiple HV channel trips in 1 hour (lower voltage and mark as "weak")
- Weak HV channel continues tripping in 1 hour (disable the channel)
- FPGA current low or very low (from DCS)
- FPGA firmware not loaded (FPGA current low + no data from that board in DQM)
- Blown fuse (FPGA current very low + no data from that board in DQM)
- Self diagnostics (lost connection to DB, fact input queue is too big)

In all of these cases, relevant experts are informed by email and/or SMS

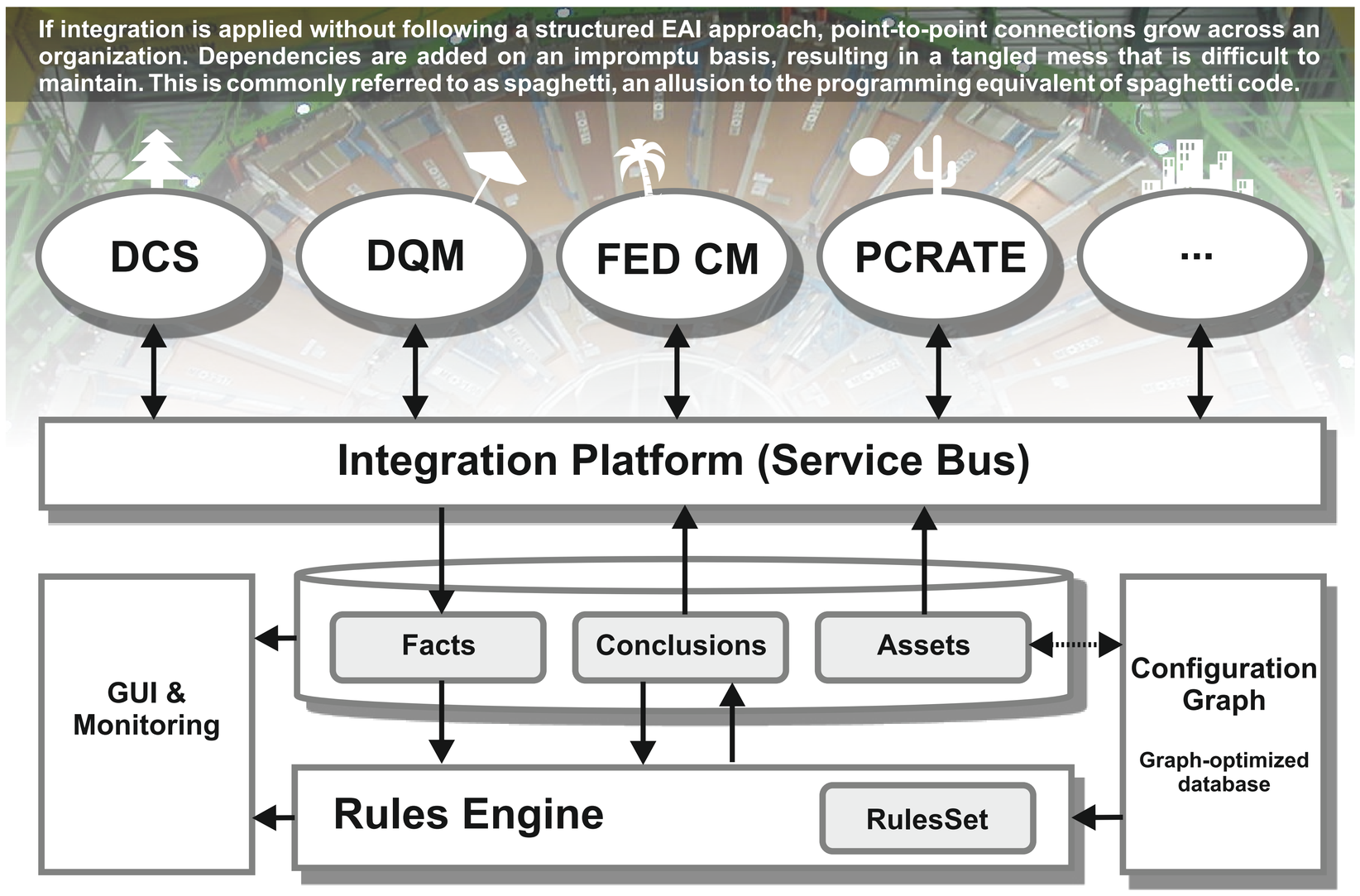
Plans

CSC operations team plans include:

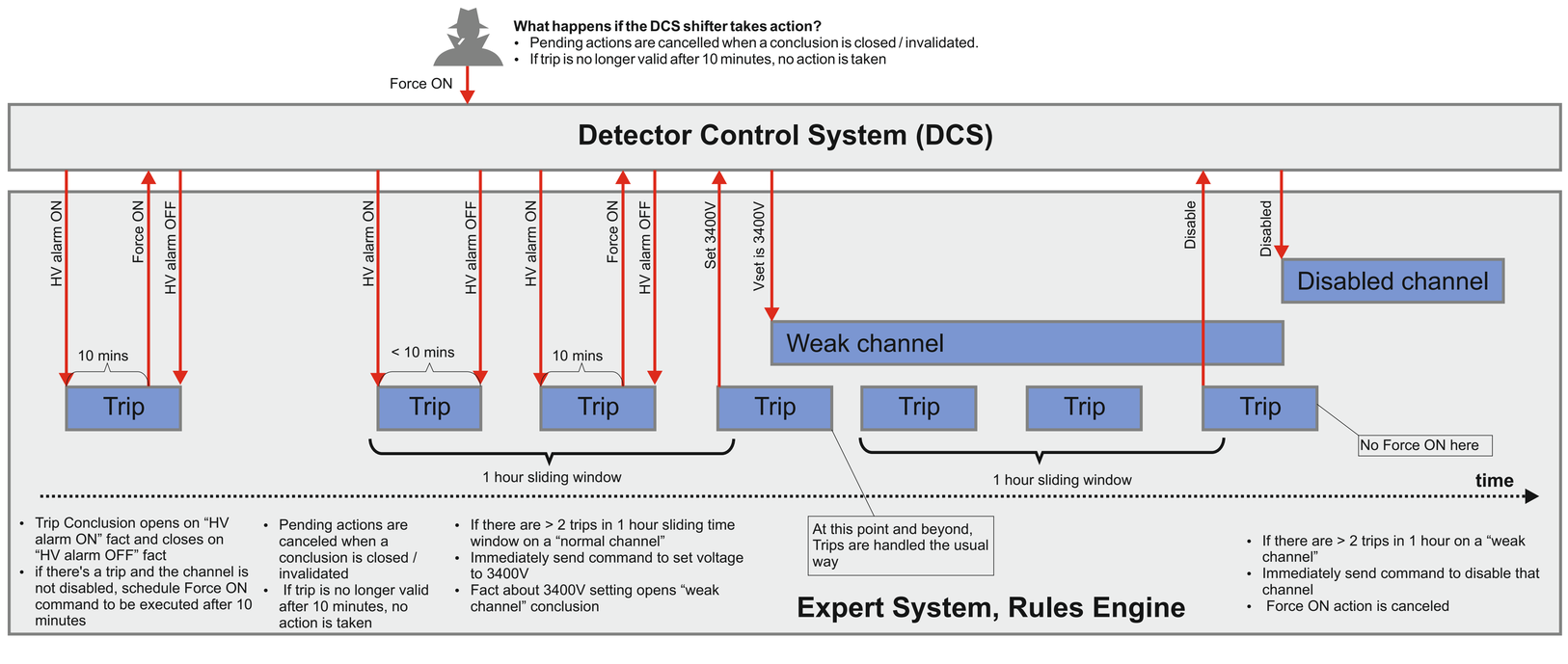
- adding more fact providers to the system,
- introducing more rules to further automate detector operations,
- improving historical data browsing and plotting tools,
- educating experts to write rules and manage Rules Engine in general.

In a broader scope, the CSC Expert System is looking for possibilities to be deployed for other CMS sub-detector control and monitoring purposes. This becomes possible after Vilnius University Faculty of Mathematics and Informatics will join the development of the system.

If integration is applied without following a structured EAI approach, point-to-point connections grow across an organization. Dependencies are added on an impromptu basis, resulting in a tangled mess that is difficult to maintain. This is commonly referred to as spaghetti, an allusion to the programming equivalent of spaghetti code.



HV trip recovery ruleset



We acknowledge funding for this project from the US Department of Energy and the US NSF