HIGH-LEVEL FUNCTIONS FOR MODERN CONTROL SYSTEMS: A PRACTICAL EXAMPLE

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Abstract

Modern control systems make wide usage of different IT technologies and complex computational techniques to render the data gathered accessible from different locations and devices, as well as to understand and even predict the behaviour of the systems under supervision.

The Industrial Controls Engineering (EN-ICE) Group of the Engineering Department develops and maintains more than 130 vital controls applications for a number of strategic sectors at CERN, like the accelerator, the experiments and the central infrastructure. All these applications are supervised by MOON, a very successful central monitoring and configuration tool developed by the group that has been in operation 24/7 since 2011.

The basic functionality of MOON was presented in previous editions of these series of conferences. In this contribution we focus on the high-level functionality recently added to the tool to grant access to multiple users through the web and mobile devices, as well as a first attempt to data analytics with the goal of identifying useful information to support developers during the optimization of their systems and help in the daily operations of the systems.

INTRODUCTION

Control Systems for particle accelerators and High Energy Physics Experiments must enable the coherent and safe operation of the equipment. Traditional control systems focus on retrieving and logging data from sensors in the field, triggering of alarms, displaying the online status of the equipment, as well as on allowing operators to send commands onto the hardware.

The strong requirements for high availability and reliability of the control systems sometimes push engineers to follow a conservative approach on the tools selected for implementation by preferring rather old although well-proven technologies, as well as to streamline the functionality of the control system.

This approach is in contradiction with the continuous proliferation of new technologies and practises in the IT domain. Moreover, nowadays users of the control systems are more and more familiar with the possibilities offered by present web and mobile applications and expect to find similar functionalities in modern control systems.

Furthermore, the introduction of modern computing technologies and practises in control systems is not only justified by the users' expectations. In fact, the utilization of recent IT techniques in the controls domain may bring an important added value to the control systems ranging from enriching the user experience to predicting the evolution of the system under supervision.

In the following, a set of high-level requirements for modern control systems will be discussed where innovative IT tools and methods play a crucial role. Several of these tools are currently being evaluated by EN-ICE to enrich the functionality of MOON [1] and at a later stage, possibly in other EN-ICE applications. Wherever applicable, the work done for MOON so far is discussed as an example.

MOON

MOON is a centralized software management and monitoring tool that builds on top of the commercial SCADA package WinCC Open Architecture [2] and the CERN JCOP [3] and UNICOS [4] Frameworks. The basic functionality of MOON was presented in a previous edition of this conference series [1]. MOON presently monitors and configures more than 130 WinCC OA based applications developed by EN-ICE and other CERN groups that supervise critical systems for the LHC accelerator, the CERN technical infrastructure, as well as for the LHC Experiments. MOON has now become a key application for the operation of the CERN facilities and of the EN-ICE on-call service.

Status Update

The basic functionality of MOON has been largely extended in the last two years. In particular, the configuration of the tool has been streamlined to add new devices to the monitoring with only a few mouse-clicks. Devices are now declared in a configuration database and inherit all characteristics like alarm handling, notification, URLs associate to alarms, from predefined templates at importation time. Moreover, all functionalities of the tool were re-worked to behave in a dynamic manner such that, newly added devices are automatically included in all services provided by the tool, e.g. web, daily and long-term reports, etc. In addition, the monitoring capabilities of the tool have been largely extended to cover:

- Front-End Computers (FEC) and WorldFIP devices [5].
- Critical parts of the EN-ICE computing infrastructure like the automatic WinCC OA license generator or the LHC dashboard [6].

Furthermore, the range of applications monitored by MOON was extended to other CERN groups and the LHC experiments. Table 1 shows the list of equipment monitored by the tool at the time of writing this paper.

MOON now also features a role-based access control model that distinguishes 4 different types of users – standard operators, application experts, on-call service and MOON experts. Moreover, all reconfiguration actions on the controls applications performed by the experts using the tool are now logged.

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ISBN 978-3-95450-139-7

Table 1: Equipment Monitored by MOON

Device Type	Quantity
Hosts	96 (91 Linux, 5 Win)
Total number of processes	33473
WinCC OA Projects	136
Monitored WinCC OA processes	4483
PLCs	257
FECs	74
WFIP	38

In the coming months, the functionality of MOON will be further increased to include the supervision of network equipment and of some elements of the electrical distribution. The communication through the CERN common cross-domain exchange protocol (DIP) [7] will also be covered to check the activity and status of the connections between clients, servers and the central name servers. Moreover, the plan also includes the monitoring of several web services that form part of the EN-ICE infrastructure.

HIGH LEVEL FUNCTIONS

The successful operation of MOON and the growing community of users have raised a new set of requirements specially in terms of accessibility to the data gathered, as well as of their processing. MOON is currently used as a sand box by EN-ICE to evaluate various new technologies and practises that could be of potential interest for other control systems at CERN.

Visualization

Although a significant effort is being done to improve the visualization capabilities of SCADA products and other frameworks used in controls, the possibilities offered are still quite limited. On the other hand, in the last few years a large set of web-based packages have become available that have brought interactive visualization to the forefront. Currently, EN-ICE is investigating and prototyping the utilization of some of these visualization frameworks directly in the control system to enrich the user experience.

Figures 1 shows an example recently added to MOON where the MooWheel [8] visualization widget was directly integrated into the tool using a custom extension [9] of WinCC OA based on the QtWebKit [10]. The Figure shows the status of the connection between different WinCC OA peers in a control system.

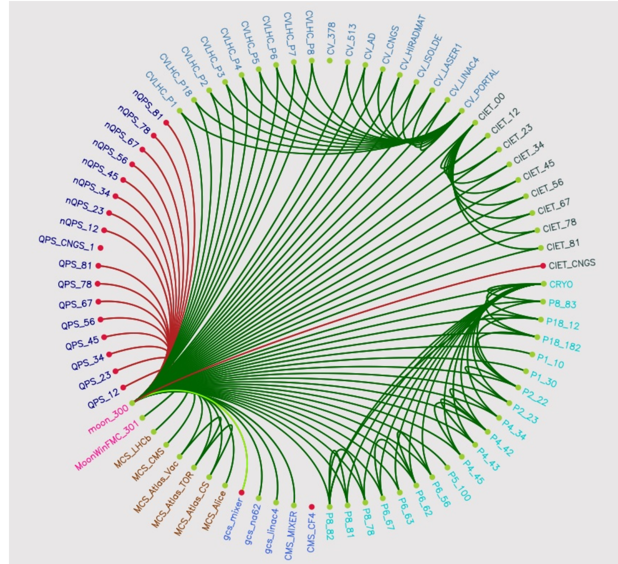

Figure 1: MooWheel javascript widget integrated in MOON to show the status of the connection of sets of remote WinCC OA applications.

Web Access

Although web access to the information gathered by the control system is a common requirement these days, depending on the environment, this requirement may be very difficult to fulfil. Web access to the data must not create any additional load on the control system and it must not expose the control system to security threats. In addition, there is a push to reuse existing user interfaces developed for the control room that were designed without taking into account possible web access. Furthermore, in the case of the LHC experiments, where the large community of users (hundreds) that could potentially consume information about the control system and the huge amount of data that must be made available, impose very strict constraints on the techniques used. All LHC experiments currently display controls system data on the web, like online status of devices, trends, list of active alarms or even log files. However, each experiment has achieved this in a different way and using distinct technologies.

In the particular case of MOON, web access to the data was not just a nice-to-have feature but a necessity due to the many users with very distinct backgrounds. Web access allows encapsulation of the underlying technologies used in the control system and provides users with an intuitive way of browsing the data. Moreover, for security reasons, all applications, as well as MOON itself, run on an isolated dedicated network. Again, web interfaces hide away this network segmentation and provides users with a direct access to the control system data.

Similarly to the visualization frameworks mentioned above, during the development of the MOON web site, many standard javascript widgets and frameworks, like the Google Web Toolkit [11], were used.

ISBN 978-3-95450-139-7

The MOON web site presents users with the current state of the devices, as well as with their metadata like the location, responsible person, etc. The status of these devices is summarized in a tree-like structure to calculate the overall state of each of the controls applications. The list of alarms currently active in the systems is also available through the web interface. It is important to mention that data and alarms corresponding to different applications domains are displayed separately presenting applications responsible with only the information they are concerned. Similarly an RSS feed allows users to subscribe to alarms for individual applications. The web site also provides access to daily and long term reports generated by MOON.

Currently the data flows from MOON to the web interfaces although it is envisaged to enlarge the functionality of the web interface to delegate various configuration actions on the application responsible, e.g. to mask alarms, to enable/disable SMS notifications or change URLs associated with alarms.

Access from Mobile Devices

The rapid spread of mobile devices in the last few years forces control system engineers to think of ways to provide access from them. However, the interest of mobile devices in controls goes beyond rendering the controls system data accessible in a convenient manner. Smart phones and tablets are equipped with a set of built-in devices that can help experts to localize equipment or to upload media files directly to the control system, e.g. photos or videos corresponding to an intervention could be uploaded as part of the documentation of the control system to assist in future maintenance operations.

However, the price to pay is that mobile devices require dedicated applications, either native or web-based. Furthermore, the still limited access to the built-in sensors in mobile devices from web-based applications makes native applications more appealing depending on the functionality required. In this sense, frameworks like Apache Cordova [12] become very interesting as they hide away from developers the details of the operating system where the applications run.

Figure 2 shows a very preliminary attempt based on JQuery Mobile [13] to provide access to MOON data from mobile devices.

Central Access to Remote Log Files

The different processes in large control systems generate enormous amounts of information that are stored in local log files. This information becomes of special relevance when it comes to troubleshooting the system. However, unlike the control system data that are typically centrally stored, traditional control systems tend to overlook these log files. This segregation of the log messages makes very difficult to establish correlations among events that many manifest in different parts of the control system and therefore, complicate the debugging of problems.

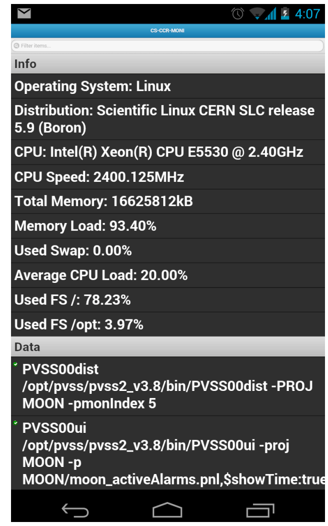

Figure 2: MOON mobile interface.

Information in log files is largely unstructured. Open source tools like Kibana [14] or commercial packages like Splunk [15] provide an efficient way to analyse and visualize these logs. A more classical, although less flexible, approach consists in imposing a structure on the data by entering them into a central database and then use one of the many web-based utilities available to display and interpret the data. In the context of MOON, both possibilities will be evaluated.

Data Analytics

Some control systems run completely unattended relying on a powerful notification machinery to inform an on-call service in the event of problems. However, the lack of a 24/7 operator may lead to situations where the control system logs incidents that, although no enough important to trigger a notification, occurred completely unnoticed by the application responsible. Furthermore, these incidents may be an indication of failures of the equipment or systematic effects. MOON is an example of this kind of controls systems where the number of incidents recorded by the tool in all applications may be of the order of hundreds without any of these events being significant enough to trigger a notification.

Data analytics techniques [16] allow analysing the events recorded offline to reveal anomalies in the systems and even to predict the evolution of the processes under control. In MOON, a very preliminary approach to data analytics was carried out to inspect data, alarms and event notifications for purely descriptive purposes. Statistical web reports are automatically generated daily that summarize the data gathered over the last 30 days. Although the work done so far for MOON in the field of data analytics can only be considered very preliminary, it has already provided useful information and has permitted to identify misbehaving processes in the control system.

A more serious attempt to make use of data analytics techniques in control systems and with a boarder scope is

ISBN 978-3-95450-139-7

currently taking place in collaboration with Siemens in the context of the CERN openlab project [17]. It is expected that MOON the fisrt EN-ICE application where any possible outcome of the collaboration with Siemens will be put in practise.

Augmented Reality

Augmented Reality (AR) consists in superimposing a computer-generated image on a user's view of a real environment, thus providing an enhanced perception of reality. AR is becoming more and more popular among other sciences and also on mobile apps. However, its application to controls systems of large Physics experiments is not widespread.

AR in control systems brings an important added value, especially for interventions. AR applications running on mobile devices may assist experts to localize faulty equipment, as well as to check, for instance, its status or the presence of the alarms while moving around in the electronics counting rooms.

At CERN, a first attempt to make use of augmented reality in the Experiments' DCS has been performed by CMS. Figure 3 shows the application developed by the CMS DCS that identifies the racks in the underground counting rooms by means of special tags and accesses the control system to superimpose data, like status, responsible person and function of the rack, as well as various operational parameters, to enhance the view of the user.

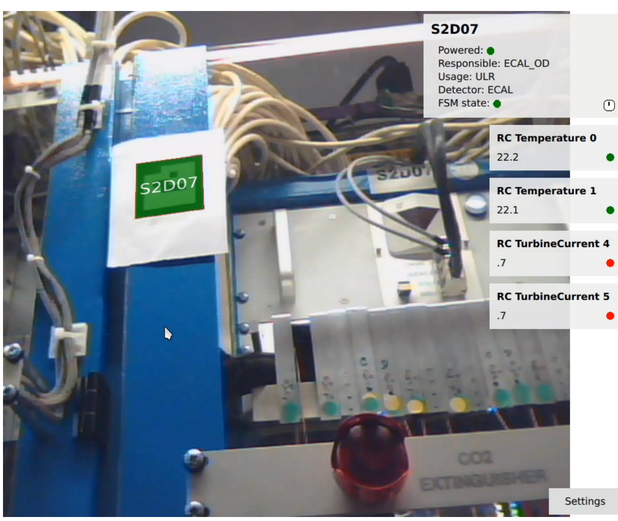

Figure 3: Augmented reality used in the CMS DCS to overlay controls system data on the operator's view as this walks around in the underground counting rooms (Courtesy of CMS DCS).

OUTLOOK

In this paper we have reviewed some novel IT technologies and techniques for their utilization in industrial control systems at CERN. In the last few years, EN-ICE, in collaboration with industry, has spawned different projects along these lines. In particular, the work done to consolidate and enlarge the basic monitoring functionality of MOON. Also efforts have been deployed to reduce its long-term maintenance. Presently, high-level user requirements in terms of presentation of the data and accessibility are being addressed. The large number of equipment monitored by MOON and the growing community of users, impose the need to delegate many configuration actions that are currently performed by the MOON experts, to the application specialists. This has triggered an urgent need to provide a web-based access to the tool from multiple devices. Furthermore, the statistical reports featured by the tool have already provided valuable information to detect anomalies in the monitored applications that were occurring completely unnoticed due to the lack of a 24/7 operator. MOON is currently used as test-bed to estimate the added value of these tools and to understand the configuration and maintenance efforts required to integrate them into the control systems. We expect that in the coming years, both user experience and the capabilities of control systems to anticipate problems will be largely enhanced thanks to these tools and practises.

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