

FIRST EPICS/CSS BASED INSTRUMENT CONTROL AND ACQUISITION SYSTEM AT ORNL*

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Abstract

The neutron imaging prototype beam line Cold-Guide 1D (CG-1D) at the Oak Ridge National Laboratory High Flux Isotope Reactor (HFIR) is used for many different applications necessitating a flexible and stable instrument control system. Instrument scientists expect a robust data acquisition system. They need a clear and concise user interface that allows them to both configure an experiment and to monitor an ongoing experiment run. Idle time between acquiring consecutive images must be minimized. To achieve these goals, we implemented a system based upon EPICS, a newly developed Control System Studio (CSS) scan system, and CSS operator interface “Best OPI, Yet” (BOY). This paper presents the system architecture and possible future plans.

INTRODUCTION



Figure 1: CG-1D neutron imaging beam line.

The CG-1D beam line is used for neutron imaging [1]. The neutron beam can be configured for continuous or pulsed beam operation with a chopper, as shown in Figure 1. Apertures with different diameters D (pinhole geometry) are used at the entrance of the helium-filled flight path to allow L/D variation from 400 to 800, L being the distance between aperture and detector

where the image is produced. Samples sit on a translation/rotation stage for alignment and tomography purposes. Detectors for CG-1D include charge-coupled device (CCD) cameras, a micro-channel plate detector with 40 micron spatial resolution (planned for time-of-flight neutron imaging experiments), and ${}^6\text{LiF}/\text{ZnS}$ scintillators varying from 50 to 200 microns. Work on neutron imaging specifically supports the development of the future Versatile Neutron Imaging Instrument (VENUS) at SNS, which will be dedicated to neutron imaging with an emphasis on Bragg-edge contrast imaging. Applications include energy storage, technologies – particulate deposition in vehicle parts,

plant system biology, plant-soil-groundwater system [2], food science and archeology, etc.

The initial Data Acquisition (DAQ) and slow control system was Microsoft Windows based and custom designed. Applications for chopper and motor control were implemented in Microsoft Visual Studio C++ and National Instruments LabView. The Python scripting language was used for the Graphical User Interface (GUI) and also to integrate various experimental components.

Unfortunately, the camera, motor and automation software were not integrated, requiring users to access at least three different computers in the process of performing an experiment. Dissimilar user interfaces required significant time for user training and assistance. There were very limited means of monitoring the progress of long-running experiments. Down time was unacceptably high.

Because of the situation described above it was decided to replace the entire control system. In the new system EPICS was used for slow control of the motors and camera. An automated and robust system for the experiment control and data acquisition was implemented based upon the CSS Scan System that is described below.

Most users are self-sufficient after just a short introduction on how to log in, open the operator screen, move motors, take test pictures, start a scan, and note the predicted finish time. This has significantly reduced the burden on instrument personnel.

ARCHITECTURE

Overview

The goal is to allow beam line users to monitor, control and automate the experiment. The experiment data, typically consisting of numerous image files taken by a camera, are written to an NFS-mounted server. The architecture of the new system is depicted in Figure 2 [3]. The system is divided into two layers. The User interface, which is implemented by CSS BOY, lives in the open network. The rest of the system sits behind a firewall. The user interface communicates with the second layer via EPICS Channel Access (CA), secure shell (ssh), and an http server. All the Input/Output controllers (IOCs) run in the beam line private network. Only read-access is available outside the beam line, such as WebOPI, but there is limited, controlled write access from the lab network through ssh for configuration and maintenance. Communications between the IOCs, which handle the hardware devices, are done through Channel Access. There is a beam line Linux server that supports data storage for the IOCs, Scan Server, and beamline-local data. Access to this server is through ssh, http and CA.

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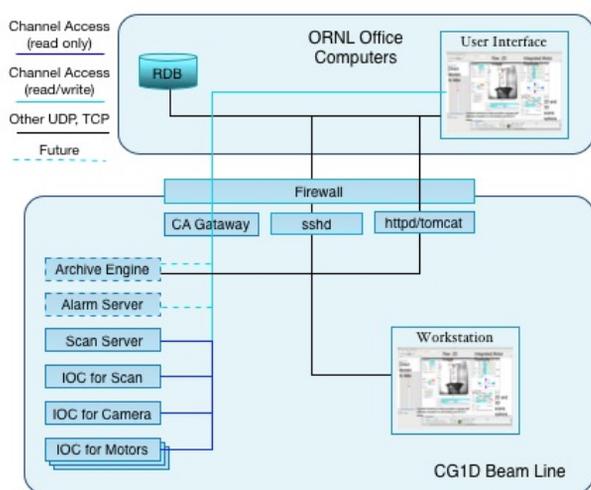


Figure 2: Layout of the system.

Scan System

The Control System Studio (CSS) Scan System [4] is newly developed and first used for CG-1D. The Scan System provides automated experiment control. Users can submit a sequence of experiments and then monitor their progress, pause, resume, or abort their execution. A typical CG-1D experiment is the Computer Tomography (CT) scan. After aligning the sample via remotely controlled motors, users then select a desired rotation stage, configure the details of the rotation range, set the camera exposure, and specify where images should be saved. Once the experiment has been defined, users can request a simulation providing an estimated duration. The experiment itself is performed automatically once launched with the “Go” button. The Scan System provides robust features of error checking, time-out handling, and readback verification during the scan process.

HARDWARE

Andor Camera

An Andor camera is used as the detector for image acquisition. The image size is 2048 by 2048 in unsigned 16 bit gray scale. We use the existing EPICS “Area Detector” support for Andor cameras. The driver supports fast image updates, but we found that they can only be viewed within one network. When transferred via an EPICS Channel Access gateway, updates are limited to about once every 10 seconds for images of this size. In practice, this is acceptable because CT scan images have typical exposure times of about 2 minutes.

Sample Positioning

The sample positioning system consists of 7 motors controlled by a Parker 6K8 motion controller. The system functions include Lift Table, Short Axis, Long Axis, Large Rotation Table, Small Rotation Table, Detector Table, and Camera Vertical Position. The standard EPICS motor record provided basic Parker 6K integration, but we needed to overcome two issues.

For the unlikely case of having to revert to the original CG-1D control software, we left an existing serial-to-ethernet converter in place that is used to connect to the motor controller. This converter, however, adds additional end-of-string characters to the communication stream, which needed to be filtered by extending the otherwise standard EPICS support software for the Parker controller.

Another problem arises when the Parker controller is power cycled. The controller will then assume that all motors are at position zero, and the default behavior of the EPICS support for this motor is to trust the controller’s position when in fact the last known motor position of the EPICS save/restore system is correct. To overcome this issue, we use a perl script that transforms the last known motor positions from EPICS into the raw Parker controller commands for re-programming the motor positions. Restoring the motor positions this way is currently a manual process, to be executed after a power outage.

Camera Focus

The RoboFocus hardware is used for camera focusing and was included in the original control system. However, the previous control system was not integrated. To set a suitable focus, instrument scientists had to manually adjust the lens by iteratively taking pictures and checking the clarity. Zooming was done manually and there were no position readouts. In the new system, sample position, lens focus, zoom, and position read are all integrated into EPICS control. The RoboFocus hardware is connected to Ethernet through Moxa terminal server. It is integrated with StreamDevice and Asyn driver and device support. A StreamDevice protocol file is created for zooming the lens in and out. The motor position can be recovered by autosave/restore.

Slits

A slit system was newly added to CG-1D beam room for adjusting beam size. Four stepper motors control the slit system, one motor for each of four BN blades. Two blades are horizontal and two vertical. All are independently controlled by a Galil Accelera DMC-4080 controller. A controller value of “0” corresponds to a closed slit so that a positive increment increases the aperture opening. If a power outage occurs, moving to maximum position can restore motor positions. Two hardware and two software limit switches for each blade are used to prevent hardware damage.

USER INTERFACE

CSS BOY provides a consistent user interface to all beam line devices as well as the Scan System (see the real-time image Figure 3). The BOY screens provide access to previously saved images, control of all motors, and the ability to submit scans.

Links provide access to operator panels for the detailed configuration of the camera and each motor. Users can

adjust image brightness, adjust the color map, track acquisition, and change motor parameters.

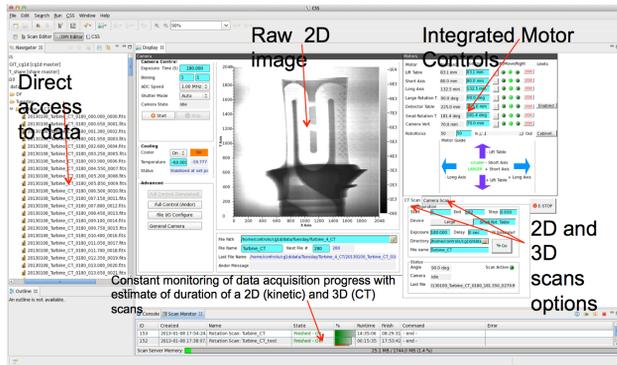


Figure 3: CG-1D main user interface.

WebOPI [5], a new development at ORNL, provides web access to CSS BOY displays. A simplified, read-only page as shown in Figure 4 allows users to remotely track the experiment progress from anywhere at any time.

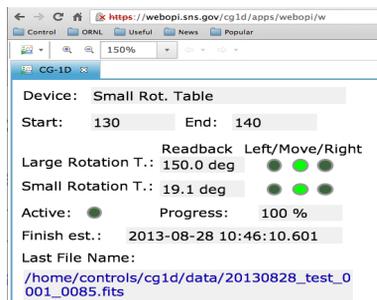


Figure 4: An example of CG-1D WebOPI.

IOC Handling

The devices on the CG-1D are controlled by six EPICS softIOCs. A web interface (Figure 5) provides IOC engineers and designated beam line personnel with options to review the IOCs' status, and allows them to start and stop the IOCs as necessary.

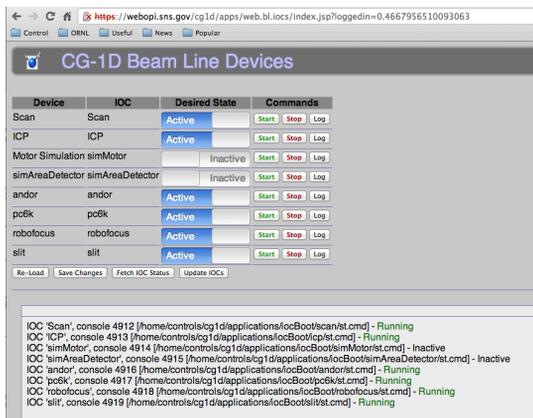


Figure 5: IOC Web interface

Software Management

A Wiki has been used from the start of this project for documentation of the instrument control system in

general, and to provide guidance specific to each beam line. Trac is used for issue tracking. Software repositories and version control is managed by Git.

SUMMARY

The HFIR CG-1D beam line has been converted to EPICS, CSS, and the new Scan System. First users of the new platform successfully performed CT scans in January 2013.

The new system has been very stable. Total downtime this year was about 2 days of production time, some of which was due to a site-wide NFS server problem. However, during that time an ongoing experiment actually continued without data loss, only the ability to monitor progress was impacted. A current concern is that the motor controller has occasionally been found unresponsive for reasons that are still under investigation.

Overall, user response has been positive, including both new users, who had a shorter learning curve, and existing users, who were able to adapt to the changes. While the previous control software required frequent assistance by instrument scientists, the new interface is significantly reduced in complexity allowing users greater independence and freeing up time for the instrument scientists.

Because of this very successful experience of the first EPICS/CSS-based beam line control system at HFIR, similar updates are now planned for beam lines of the Spallation Neutron Source (SNS) at ORNL. Specifically, the control system of the existing beam line “Engineering Materials Diffractometer (VULCAN)” is being converted, and the new beam line Ultrasmall-Angle Neutron Scattering (USANS) will use the EPICS/CSS-based control system.

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REFERENCES

- [1] <http://neutrons.ornl.gov/imaging/>.
- [2] M. Kang, H. Bilheux, *et al.*, "Water Calibration Measurements for Neutron Radiography: Application to Water Content Quantification in Porous Media," Nuclear Instrument and Methods in Physics Research A 708 24-31(2013).
- [3] SNS Instrument slow control development Wiki.
- [4] Kay-Uwe Kasemir, “CSS Scan System”, FRCOAAB01, ICALPC2013.
- [5] Xihui Chen, *et al.*, “Bringing Control System User Interfaces to the Web”, TUPPC078, ICALPC2013 proceedings.