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Application of Control Software Framework to Sample Environment Equipment in J-PARC MLF

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The instrument control software framework “IROHA2” is used for the neutron and muon experiments at J-PARC MLF. IROHA2 consists of four core software components; the device control server, the instrument management server, the sequence management server and the integrate control server. Since IROHA2 is equipped with a web user interface, the control system can be accessed remotely using a web browser. Several device modules of the device control server were developed by MLF’s sample environment team in order to be able to use the sample environment equipment for automatic measurements.

KEYWORDS: software framework, device control, automatic measurement, J-PARC MLF

1. Introduction

Many pieces of sample environment equipment such as a cryostat and a high-temperature furnace are maintained and used for neutron experiments at the Materials and Life Science Experimental Facility (MLF) of Japan Proton Accelerator Research Complex (J-PARC). Since it takes several hours to complete the start-up and shut-down of these apparatuses, and neutron experiments at MLF last from several days to a week more, the apparatuses must be controlled and monitored over a long period of time. In some experiments, conditions such as temperature need to be changed frequently during the measurements. It is not practical to have operators or experimenters constantly on the instrument from the beginning to the end of the experiment. Therefore, a control software is needed to use the sample environment equipment in automatic measurements and to monitor their status from outside the experimental instrument. Moreover, in order to use these apparatuses on multiple instruments, such software must be common throughout a facility.

We have developed IROHA2 [1,2] as a standard software framework for instrument control and experimental control at MLF. IROHA2 provides functions to implement apparatus monitoring and controlling, performs automatic measurements, and realizes remote monitoring and controlling through a web user interface. IROHA2 consists of four core components: the device control server, the instrument management server, the sequence management server and the integrate control server. By incorporating a program called a device control module into the device control server, it is possible to monitor and control the apparatus from a web user interface and to retrieve a log of the apparatus. The MLF's sample environment team has been developing modules for sample environment equipment. In this article, we provide an overview of IROHA2 and descriptions of the modules for sample environment equipment.

2. Overview of IROHA2

The four servers of IROHA2 are written in the scripting language Python and use the web application framework Bottle [3]. The CSS library Bootstrap [4] is used for the front end to achieve a responsive user interface. Figure 1 shows the relationship between the four servers of IROHA2 and the web user interface. Each server communicates XML messages over HTTP.

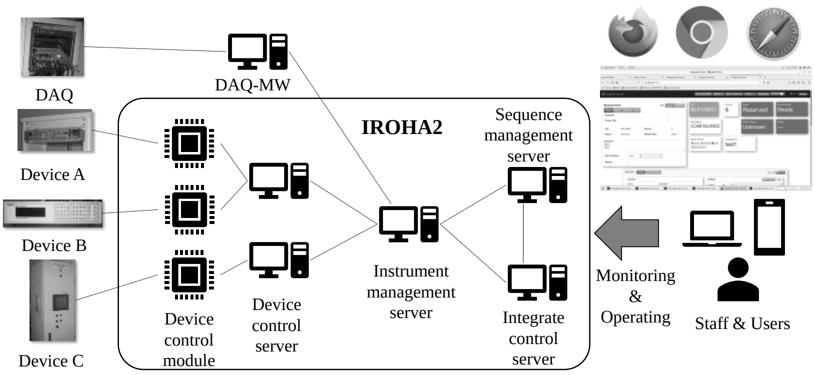

Fig. 1. Relationship between the four servers of IROHA2 and the web user interface.

The device control server monitors and controls apparatuses and retrieves logs of apparatus. The device control modules are Python programs that communicate directly with apparatuses. The device control server provides functions for connecting to apparatuses, acquiring the status, and sending commands. The modules override the functions in order to enable us to monitor periodic status, to do GUI-based operation, and to log in a unified format. When controlling newly introduced devices with a device control server, it is necessary to create the device control module.

It is possible to run multiple device control servers per IROHA2 system as shown in figure 1. This makes it possible to easily add a set of common sample environment equipment and servers that control them to an IROHA2 system in the instrument.

The instrument management server manages multiple device control servers and controls the data acquisition (DAQ) system; it commands DAQ middleware [5] to start and stop measurements and stores the raw data and its metadata. In addition, it processes requests from the sequence management server and the integrated control server. The staffs and users can define the combination of apparatuses used in the experiment and adds the status of those apparatuses to the metadata at the time of measurement.

The sequence management server performs automatic measurements. Commands to control the measurement and to control the apparatuses are provided, and these commands are combined to construct the sequence of automatic measurements. The commands written in the sequence are sent to the DAQ system and the device control server through the instrument management server.

The integrated control server can monitor information from all servers centrally. It can also operate apparatuses and control measurements and sequences. The server has the function to generate static HTML page and distribute information to the outside world on a regular basis.

3. Device control modules for sample environment equipment

By controlling the sample environment equipment with IROHA2, we can realize advanced measurements and operation labor savings. Therefore, MLF's sample environment team has been developing several device control modules of IROHA2 device control server for the sample environment equipment. Figure 2 shows the sample environment equipment in the MLF. In this section, we introduce the functions of the modules, and what they accomplish in experiments.

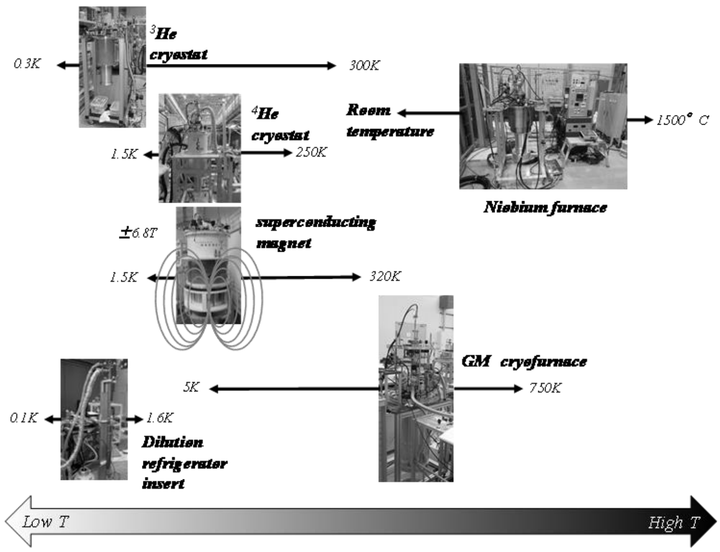

Fig. 2. Sample environment equipment in the MLF.

3.1 Low temperature equipment

The ^{4}He cryostat is a low-temperature apparatus and, covers the sample temperature in the range from 1.5 to 250 K. In addition, the sample can be rotated. The device control module can monitor and change temperature, rotate the sample, and acquire the status of apparatus errors. The operations of temperature control and sample rotation can be incorporated into a sequence of the automatic measurement. Therefore, the measurements can be performed automatically after a predetermined temperature or angle is reached. By using this sequence, it is possible to automate the process of alternating sample rotation and measurement in a short period of time.

The ^{3}He cryostat is used for the measurements in the range from 0.3 to 300 K. This cryostat includes a one-shot ^{3}He system, and its holding time is about 5 days at the lowest temperature. Therefore, this apparatus requires the operation for recondensing ^{3}He in a long duration experiment. The cryostat also has a rotary stage. The device control module is currently under development. The module will be able to operate similarly to that of the ^{4}He cryostat. In addition, it will be capable of automatic operation for recondensing ^{3}He and for cooling the system from room temperature to the lowest temperature and automatic shutdown operation.

The superconducting magnet is capable of cooling samples with liquid ^{4}He and applying a magnetic field. The sample temperature is controlled in the range from 1.5 to 320 K, and the magnetic field is controlled in the range from -6.8 to +6.8 T. The module can control temperature and rotation angle similarly to that of the ^{4}He and ^{3}He cryostats. When we change the magnetic field, the superconducting magnet needs several processes, such as connecting the circuit of the power supply and magnet, changing the field with an appropriate sweep rate, and then disconnecting the circuit to turn off the power supply. Since the module can operate these processes automatically, users need only to set the magnetic field value. Safe operation of the magnet has been realized by this module. Demagnetization around the magnet is carried out at the end of an experiment. This apparatus can perform the demagnetization operations by making a sequence to repeat changing the magnetic fields, which can reduce loads on users and staffs. In addition, the module can show an occurrence of magnet quench. It warns of a danger by a rotating light when a quench occurs.

The dilution refrigerator cools a sample to temperatures that cannot be reached with a ^{3}He cryostat by using the ^{3}He-^{4}He mixture. This is an insert that can be used by combining the above-mentioned ^{4}He cryostat or the superconducting magnet. The sample temperature can be controlled in the range from 0.1 to 1.6 K. Combined with the superconducting magnet, the sample can be cooled while a magnetic field is applied. The entire dilution refrigerator insert, including the sample, can be rotated by setting onto the ^{4}He cryostat or the magnet. The device control module is currently under development. The module will be able to operate similarly to that of the ^{4}He cryostat.

The Gifford-McMahon (GM) cryo-furnace is used for the measurement in the temperature range from 5 to 750 K. It is useful to perform measurements from low to high temperatures seamlessly. The sample can be rotated in the same way as the ^{4}He cryostat. The module can operate similarly to that of the ^{4}He cryostat.

3.2 High temperature equipment

The niobium furnace heats samples using low-voltage and high-current resistance heaters. The sample temperature can be controlled in the range from room temperature to 1500 °C. In addition, the sample can be rotated.

The device control module can monitor the temperature and rotate the sample. However, because the temperature cannot be controlled remotely for safety reasons, commands for temperature control are not implemented in the module. Moreover, we have developed a system that turns on a warning light when an abnormality occurs and further notifies the integrated control server of them. Figure 3 shows the configuration of this system. By connecting the control panel of the niobium furnace to the cabin alarm panels of the indicating

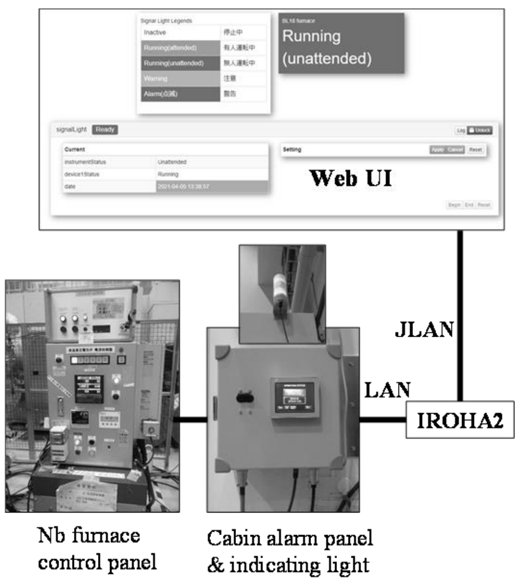

Fig. 3. Configuration of remote monitoring system for the niobium furnace.

lights installed in each beamline, the indicating lights can be turned on when an abnormality occurs in the apparatus. The integrated control server obtains the information from the control panels of the warning lights via Ethernet communication and we can remotely check the information via web user interface.

4. Conclusion

At J-PARC MLF, we have developed a software framework, IROHA2, for instrument control and automatic measurements. MLF's sample environment team has been developing the device control modules to control the sample environment equipment from IROHA2. By developing the modules, we realized an unattended control and remote monitoring for several sample environment equipment.

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