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STATE MACHINE DESIGN FOR CSNS EXPERIMENT CONTROL SYSTEM

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Abstract

This paper directs attention to the state machine design of the neutron scattering experiment control system in CSNS. The task of the software system is to complete the experiment on spectrometer, the purpose of the state machine design is to work with each other among the subsystems. Spectrometer experiment in CSNS spectrometer by internal control, data acquisition and analysis software, electronics, detector, sample environment and many other subsystems combined，this paper focuses on the introduction of the design details of state machine.

Keyword: CSNS, Neutron Scattering, Experiment Control, software design, EPICS.

INTRODUCTION

CSNS (China Spallation Neutron Source) includes a powerful linear proton accelerator, a rapid circling synchrotron, a target station and three neutron instruments. CSNS Experiment Control System works as an overall controller of all kinds of devices, as well as a manager in charge of running the procedure of experiment correctly and stably [1]. Generally, a neutron experiment at CSNS comprises several interacting modules like control system, detectors, data acquisition(DAQ), and physics analysis. Then control system will gather all the parameters user submitted and compose scan scripts for automation. During the automated execution of scan scripts, control system doesn't only interact with other modules by signaling start/stop to DAQ and Physics Analysis, but also gathers and assembles configuration data and process value, integrates them into a summary file for users tracing back the process of the experiment. Besides, errors are also required to be handled properly in the whole course of experiment process. Moreover, the procedure of each module is changeable on different type of spectrum. On this account, there must be a simple extensible and efficient interacting mechanism that reduces complexity and enhance extensibility when requirement varies in the future, which leads to a stable and maintainable control system. In such design, control system provides GUI for users submitting experiment proposal and making up the controlling procedure of an experiment task. The framework of the CSNS control system is based on EPICS. In a view of data, serving as a data transmission medium, EPICS is a reliable and convenient technique to guarantee stable sending and receiving process value(PV) [2]. PV is designed to be the necessary and sufficient data layer that other modules need to pay attention to. In a view of process, it is also required that specifically stating the interactions between modules to ensure the system handling all kinds of actions under different operating conditions. In this paper, the finite state machine mechanism will be mainly explained how to decompose and process the multiple modules interactive experiment task through the state machine and EPICS service. It provides a more standardized and effective method for task decomposition and processing.

Table 1: Data Flow of a Normal Experiment

Phase	Action	Datafile
Generation	Fetch Configuration information into file.	Spectrum configured Nexus file.
Static data collecting	Collect experimental parameters on OPI.	Experimental proposal Nexus file.
Dynamic data gathering	Gather process values.	Experiment report
Output	Adding the locations of DAQ file.	Experiment summary

DATAFLOW OF EXPERIMENT CONTROL

From a data flow perspective, an experiment summary file, which is generally the product a control system

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should yield to the users for their analysis needs, is typically generated from configuration of all subsystems such as shutters, choppers, slits, then filled by the users with proposal information and experiment parameters, and logged process value during experiment, at last put all DAQ data files together. As a consequence, the data flow of a normal neutron experiment is described in the table 1.

PROCESS OF EXPERIMENT CONTROL

In accordance with experiment data flow, the experiment process can be also designed to four phases, showing in Figure 1. A state machine is introduced into the interactive process, for control system organizing the process flow of the interactive modules such as DAQ, Online Analysis and monitor. On one hand, control system is in charge of the state transitions, that is, deciding whether the experiment should step into the next phase as well as get its own state transited. On the other hand, state of the control system also depends on the states of other modules.

In the process of interaction between the control system and other modules, a state machine is designed for the managing of the state transition of the whole experiment system. The state machine simplify the interaction of modules. Figure 2 illustrates a normal experiment activities flow. 1)The experimental task submitted by the user can be either an instruction step by step or a script file for automation, to notify the state transition. 2)In each state, the other modules proceed their own tasks and signal the state machine for next phase when it completes. 3)Meanwhile, control system also has to perform certain tasks such as RUN generation, data collecting, summary file output. 4) If and only if the control system completes its own tasks and all modules signal their completion, then the state machine transit to the next state. An important advantage and necessity of using state machine to modeling the experiment controller is that in some experiment ,order of phases showed in Figure 2 varies a lot.

One example is the Looping of phase II and III with multiple runs in a single experiment. To implement it, you can just simply change your code by adding a Loop on state II and state III, keeping away from change all the instructions flow interacting with other modules. Thus, it gives the simplification for the user to organize their task scripts by only changing the procedures of transitions among a few states, other than writing specific code for each experiment. Obviously, well encapsulated states set design brings clearance and concise to the whole process.

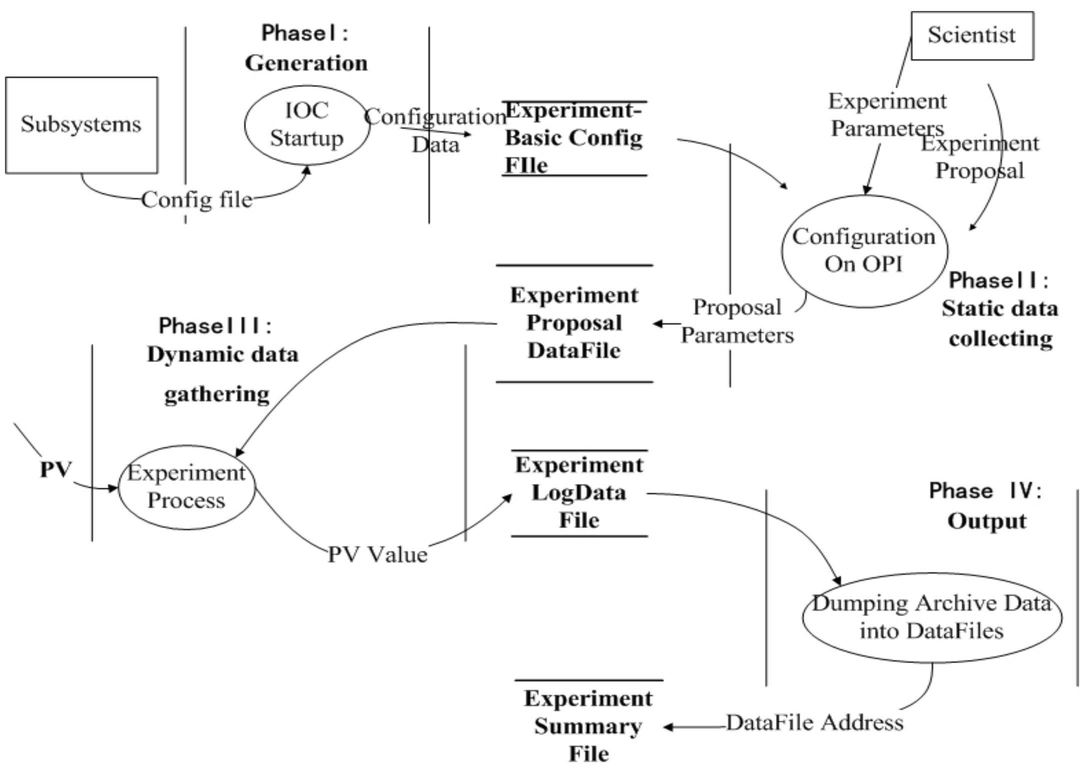

Figure 1: Experiment data flow.

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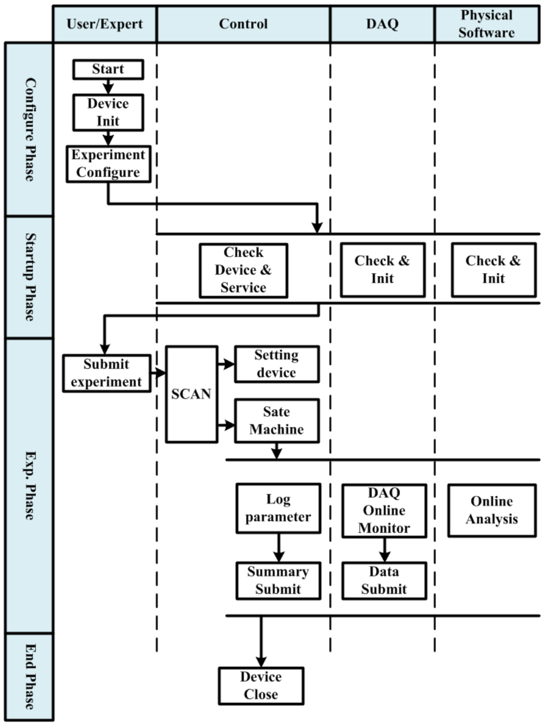

Figure 2: Interactive process of an experiment.

STATE MACHINE DESIGN

In CSNS neutron experiments, the scientists propose the goals of the experiment, then control system transforms the physics proposal into the concrete control actions. In the meantime, DAQ system and online analysis system are both involved. DAQ system, combined with detector and electronics, is in charge of the acquisition and storage of neutron experimental data under the instruction of control commands. Online analysis system analyses the data from DAQ then display the results to the scientists. During the experiment, control system connects all front hardware to the software, executes the instructions and scripts [3]. The other modules carry out their own tasks in each state under the controlling of the state machine.

It is important to point out that the sequence of execution of DAQ and Online Analysis is variable. For example, in normal neutron experiment DAQ system must starts after the online analysis begins, in case of any data lost and cause inaccurate analysis results. Quite on the contrary, in some test experiment, usually a scan of several points, tuning for the best experiment environment, the online analysis will repeatedly start/stop in a loop. In such case DAQ should start before online analysis for unnecessary multiple start/stop.

In the standard sequence of the states transition of a normal experiment, 5 Commands are described in Table 2.

Table 2: Commands Definition

DEFINITION	COMMANDS
Start Online Analysis	CONF
Start DAQ system	START
Stop DAQ system	STOP
Stop Online Analysis	EXIT
Reset all states	CANCEL

Correspondingly ,7 states are designed as: Waiting, Initialized, Ready, Running, Ended and Error, as shown in Table 3.

- Waiting state is a 'head state' when state machine start-up or reset up. It will unconditionally transit to the Initialized state.
- Initialized state means the control system and all the other subsystems are ready for configuration. When a CONF command is signalled by user or the script, online analysis starts and return a success signal. Then control system will transit to Ready state.

Table 3: The State Transition Table

States / Events	Waiting	Initialized	Ready	Running	Ended	Error
/	Initialized					Waiting
CONF signaled **Online Analysis startup**		Ready				Waiting
START signaled **DAQ startup**			Running			Waiting
STOP signaled **DAQ stopped**				Ended		Waiting
EXIT signaled **Online Analysis stop**					Initialized	Waiting
CANCEL Signaled						Waiting
Error occurred	Error	Error	Error	Error	Error	Error

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- Ready state indicates that the experiment data can be acquired for online analysis. A signalled START command orders DAQ system to start the data acquisition and storage routines. Control system will notice DAQ starts successfully then make a state transition to Running state.
- Running state shows that all the experiment system is running. If everything goes well, online analysis system will display the plots and graphs onto the screen. When the experiment reaches the predefined end condition such as time, proton charge, a STOP command will be signalled for DAQ to stop. Then control system will make a transition to Ended state.
- Ended state means DAQ has already stopped. All the experiment data is analysed. At this time, An EXIT command should be signalled for online analysis to stop and reset the control system state to Waiting.

In the above each state, any exception or fault occurred, control system state will make a transition to Error, waiting for manually handling. When a CANCEL command is signalled, control system will transit to Waiting. A state diagram shown in Figure 3 illustrates the design of the state machine.

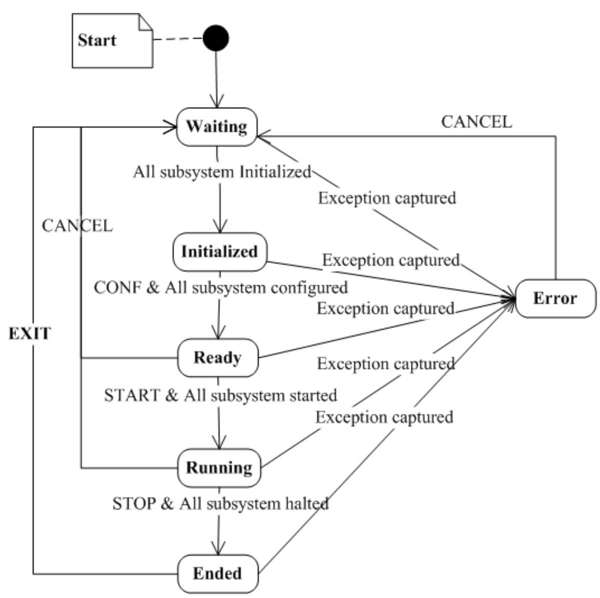

Figure 3: State diagram of control state machine.

IMPLEMENTATION

Based on the design of the above state machine, program can be easily coded and tested. In CSNS implementation, state machine is deployed on IPC that installed CentOS System on which EPICS (Experimental Physics and Industrial Control System) and the extension Sequencer are compiled and installed. State machine is coded using SNL (*State Notation Language*) language running on Sequencer, which is one of the most famous EPICS extensions. It smoothly integrates with PV and depends and builds on EPICS base. Also, it can escape to C code seamlessly.

CONCLUSIONS

After the construction of hardware and software, the current state machine has successfully complied and implemented on neutron spectrum systems in accord with the design logic [4].

The completion of CSNS will be in 2018. At that time experiment control system will be run in the real time, such that later on various of on-site deployment and software operation debugging is expected to get the system optimized.

REFERENCES:

[1] L. Hu, J. Zhuang, Y. Chu, D. Jin, "Design of Interface Between EPICS System and Device Driver of BeckhoffPLC", Nuclear Electronics & Detection Technology, 2013, 33(02):149-151.

[2] EPICS, `http://www.aps.anl.gov/epics/`

[3] J. Zhuang *et al.*, "The Design Status of CSNS Experimental Control System", in *Proc. 13th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'11)*, Grenoble, France, Oct. 2011.

[4] J. Zhuang *et al.*, "The Performance Test of F3RP61 and Its Applications in CSNS Experimental Control System", in *Proc. 13th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'11)*, Grenoble, France, Oct. 2011.