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Recent Progress in the Development of MLF EXP-DB in J-PARC

Kentaro Moriyama[1] and Takeshi Nakatani[2]
[1] Neutron Science and Technology Center, Comprehensive Research Organization for Science and Society (CROSS), 162-1 Shirakata, Tokai-mura, Naka-gun, Ibaraki, Japan
[2] Materials and Life Science Division, J-PARC Center, Japan Atomic Energy Agency (JAEA), 2-4 Shirakata, Tokai-mura, Naka-gun, Ibaraki, Japan

E-mail: k_moriyama@cross.or.jp

Abstract. The MLF Experimental Database (MLF EXP-DB) is a core system aimed at delivering advanced services for data management and data access in J-PARC/MLF. Its main role is to safely and efficiently manage a huge amount of data created in neutron instruments and provide effective data access to facility users. It is a web-based integrated database system based on a three-layer architecture model. By collecting experimental data and associated information, e.g., proposal, principal investigator, and samples from instruments and other business database systems, it creates an experimental data catalog and enables facility staff and users to access this catalog by providing them with web portals. Recently, we redesigned the MLF EXP-DB to enhance its availability and scalability toward achieving a full-scale operation in the future. In addition, we developed web portals to improve its usability. This paper presents the details of the recent developments and the current operating status of MLF EXP-DB.

1. Introduction

A huge amount of experimental data can be produced in neutron scattering experiments using current high-intensity beams; therefore, data management is a crucial factor in the research workflow. Data should be managed efficiently for a long duration and delivered quickly to users in order to promote the acquisition of scientific results. Metadata is useful for the utilization and management of such data. Thus, we are developing the MLF Experimental Database (EXP-DB) as a core system in the data management infrastructure of J-PARC/MLF [1], which creates experimental metadata by collecting experimental data from instruments and provides data management services and access to facility staff and users via web portals. This system is currently under limited operation for data management on a trial basis with several instruments in J-PARC/MLF.

One of the features of MLF EXP-DB is an XML database system. In MLF, the measurement condition is recorded as a measurement log in XML format by IROHA, which is a standard measurement control software framework in MLF [2], and this log can have different XML structures relative to the given measurement conditions. As the XML database has flexibility and extensibility for the data structure, this architecture is suitable for handling our measurement logs. However, the XML data size can easily become large owing to structural information such as tags and attributes, and its analytical process is generally heavy. Therefore, implementing features to effectively and stably store, search, and manage a large amount of XML data is challenging. In addition, facility users must have quick and effective data access. Thus, the issues that need to be resolved to achieve a full-scale operation of MLF EXP-DB in the future are as follows:

- High reliability is required for a core system; however, the conventional MLF EXP-DB runs on a single physical server. By removing this single point of failure, service outages due to system failures and maintenance should be avoided as much as possible.
- Scalability for data collection is required. The load for data collection depends on the data production rate, which is increasing continuously with improved instrument performance and neutron beam intensity. The beam intensity is scheduled to increase according to the development plan for accelerators in the facility.
- A web portal that enables effective and quick data access should be provided to facility users. A data search function is especially important to find required data for analysis from a large amount of experimental data.

To address these issues, we redesigned MLF EXP-DB and developed the web portal as follows:

- **High availability:** We enhanced the reliability of MLF EXP-DB by improving it as a redundant distributed system.
- **Scalability:** We redesigned the MLF EXP-DB to a scaled-out configuration. It is possible to scale the system performance based on the data rate.
- **Flexible data search:** We improved the web portal for data access by implementing a flexible data search function.

2. MLF EXP-DB

MLF EXP-DB is a web-integrated database system that employs Java-based commercial middleware with an XML database management system named “R&D Chain Management (RCM) System Software” [3], which is based on a three-layer architecture model comprising three primary components: RCM-Web, RCM-Controller, and RCM-DB. RCM-Web provides the system’s web interface, and the RCM-Controller processes requests from RCM-Web and queries for RCM-DB. RCM-Controller has a workflow engine that executes the workflow described in the XML format. All MLF EXP-DB functions are implemented with the workflow. RCM-DB is a hybrid XML database system, i.e., the XML database is implemented as a relational database and the XML tree is registered in relational tables. After collecting experimental data from instruments, RCM-Controller creates metadata and registers them in RCM-DB as an experimental data catalog. Facility users and staff can access this catalog via the RCM-Web web portal. To reduce communication overhead with a large volume of XML data among these components, all components run on a single physical server.

3. Recent developments

3.1. High availability

To improve the reliability of MLF EXP-DB, we redesigned the system to remove the single point of failure. The system, which previously ran on a single physical server, was upgraded to a redundant distributed system comprising two physical servers with the same specifications in a switch-over relationship. This system configuration realizes high availability, especially for data collection from instruments. In addition, for MLF EXP-DB, we deployed a redundant front-end web server, which is used for data management by facility staff. Figure 1 shows a schematic of the current system, and Table 1 shows the MLF EXP-DB server specifications.

Both redundant systems adopt an active-standby deployment model. In MLF EXP-DB, the active server collects experimental data and provides a web portal for data access through a front-end web server. Real-time replication among the databases of the active and standby servers is also performed. When a system failure or maintenance occurs, executing a switching script migrates the operation from the active server to the standby server. It is possible to complete operational migration within 30 min. Conversely, automatic failover of the front-end web system is realized using a cluster heartbeat. The active and standby servers share a virtual IP address; thus, facility staff can access the web portal easily.

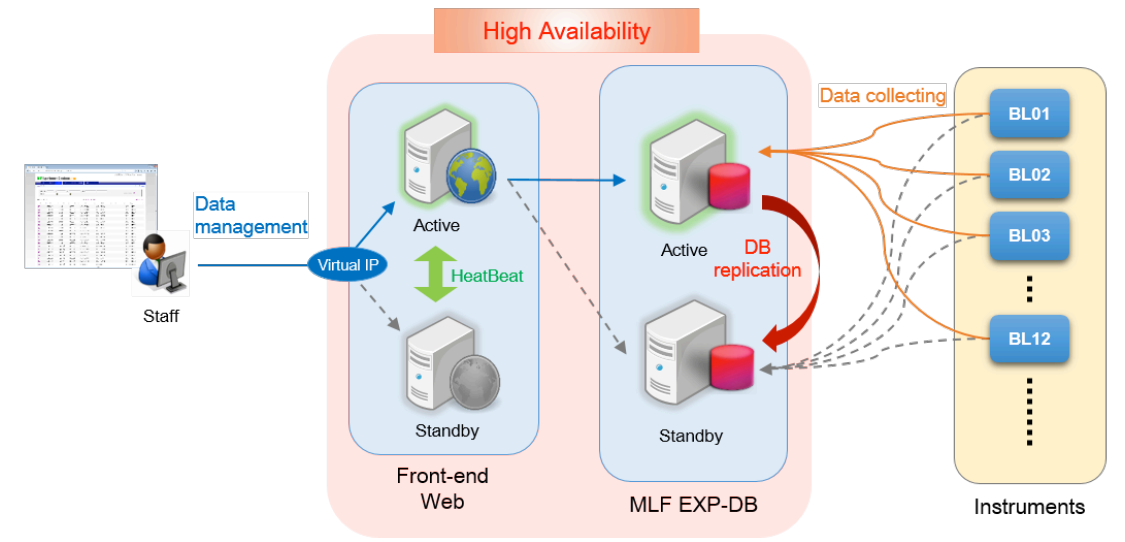

Figure 1. Operation of the redundant distributed system

Table 1. Server specifications

Item	Specification
OS	Red Hat Enterprise Linux 6.3 64 bit
Processor	Intel Xeon E5-2407 v2, 2.4 GHz, 4 core × 2
Memory	128 GB
HDD	SAS 7,200 rpm, 1 TB × 3 RAID 5
Network	1 Gb Ethernet × 4 ports
Power Supply	Dual, hot-plug redundant power supply (350 W)

3.2. Scaling-out

Although XML has high flexibility and extensibility in terms of data structure, the amount of data is generally becoming large, and the loads for creation and analysis of XML data are becoming heavy; this results in significant performance degradation. To improve the performance of MLF EXP-DB, we scaled out the system; this enables data collection load balancing and partitioning of increasing amounts of XML data. The improved system comprises two nodes, and each node is a redundant system (described in the previous subsection). This architecture allows us to improve performance by adding a node in response to the data rate. Data access transparency in the distributed system is provided by Node 1 acting as a master server that receives all requests from a user and performs cross-searching over nodes.

Figure 2 shows a schematic of the system. In MLF, 20 instruments are currently under operation, and these instruments are deployed in two experimental halls in the facility. Two nodes in the scaled-out system, i.e., Node 1 and Node 2, are allocated to instruments in the first and second experimental halls, respectively. Users can access data via the web portal using the front-end web server.

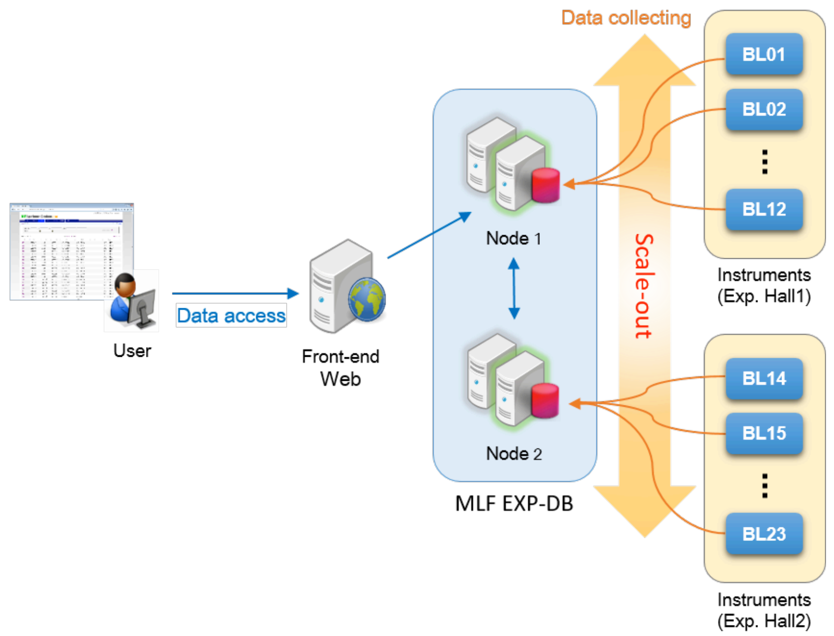

Figure 2. Scaled-out system for data collection and unified web interface for the distributed system

We made a preliminary evaluation of the data collection performance for the scaled-out system. Figure 3 shows the data collection throughput, which includes the process of creation and registration of metadata after collection of experimental data. In this case, the number of simultaneously collected datasets is 200, and each dataset includes raw measurement data and log files. The size of the raw data is approximately 500 MB, and the size of log files is less than 1 MB. The number of tags in the XML format log file is 754. These are typical data sizes in MLF. However, the number of tags changes in response to the number and type of devices used. The throughput gradually decreases with the number of processes; however, it is possible to improve performance by adding a node.

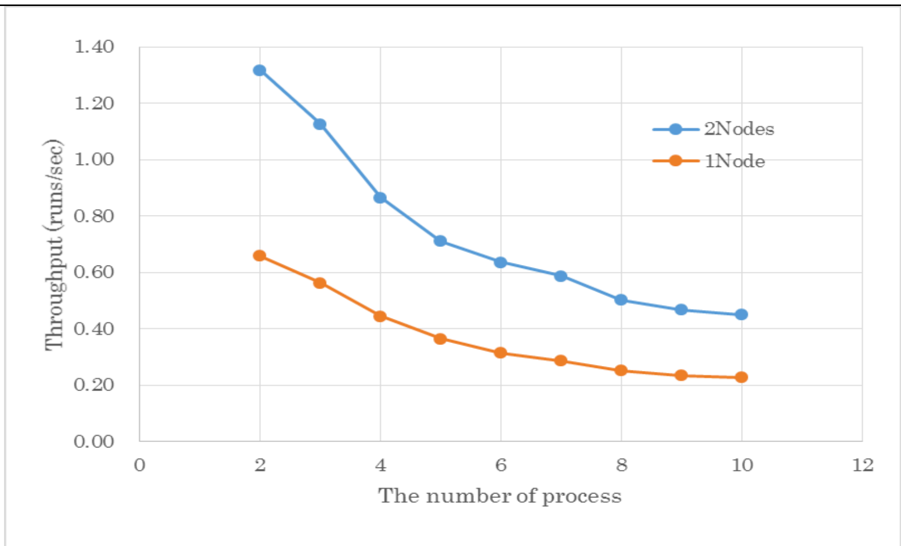

Figure 3. Data collection throughput in the scaled-out system

3.3. Flexible data search in web portal

A quick and easy search for the data required for analysis is important. Therefore, we implemented a flexible data search function in the web portal that enables search of various experimental metadata.

- **Experimental Proposal:** Proposal ID, Title, Primary investigator, Period
- **Measurement:** Experimental ID, Run No., Comment
- **Sample:** Sample ID, Substance name, Chemical formula
- **Device condition:** Device type, Setting parameter, Physical value

A search with the device condition is useful for data generated under a sequence of measurements by changing sample environmental conditions such as temperature and magnetic field. However, a search for metadata with a flexible XML structure in the XML database can significantly degrade performance and provide insufficient results. Furthermore, the user must be able to search for data without considering a complex XML structure.

Thus, we developed an effective search procedure using a search template, which is an XML subset with a different structure relative to the device type. Figure 4 shows an example measurement log, search template, and function. The search template includes the device name, axis name, and type of physical value, such as a string or a numerical value. When a new device is introduced, the instrument staff must create a template. The user can execute a search by selecting devices whose templates are registered for each instrument.

a)

```
<logs>
  <params>
    <comment/>
    <intervalStanby>10</intervalStanby>
    <intervalMeas>1</intervalMeas>
    <axisInfo>
      <axisRec>
        <axisName>phi</axisName>
        <inpPos>50.000</inpPos>
        <curPos>0.053</curPos>
        <motorSts>Stop</motorSts>
        <motorStsCode>1</motorStsCode>
      </axisRec>
      <axisRec>
        <axisName>ome</axisName>
        <inpPos>50.000</inpPos>
        <curPos>0.249</curPos>
        <motorSts>Stop</motorSts>
        <motorStsCode>1</motorStsCode>
      </axisRec>
    </axisInfo>
  </params>
  <devName>GONIO2AXES</devName>
</logs>
```

b)

c)

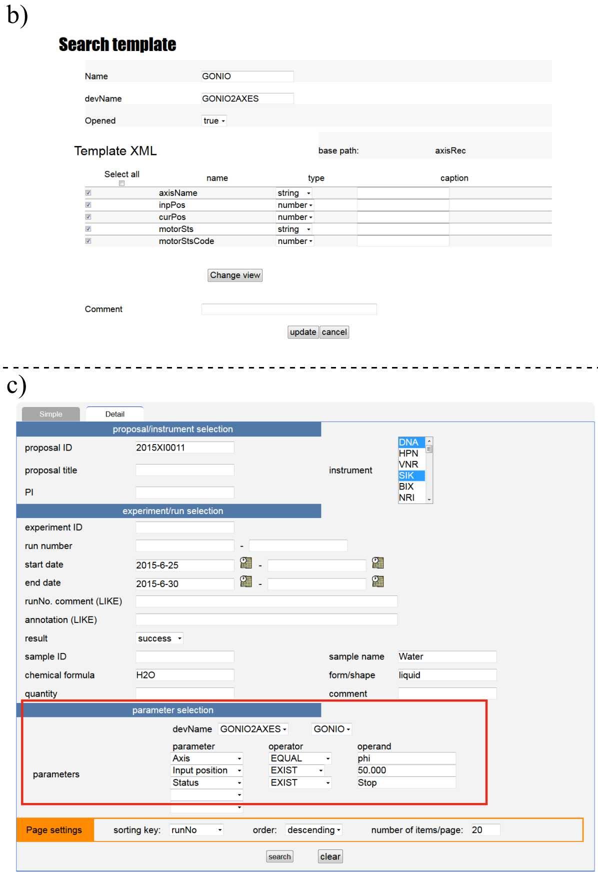

Figure 4. Flexible data search with device condition: a) device condition in the measurement log, b) screenshot of search template management, and c) screenshot of flexible data search

4. Current status and future plan

Currently, data management using MLF EXP-DB is being performed on a trial basis with some instruments, i.e., BL02, BL11, BL17, and BL18 in the MLF. In this trial operation, the data produced in previous experiments are primarily collected to accumulate metadata and verify the required information in the experimental data catalog. We plan to start a full-scale operation of MLF EXP-DB soon, which will enable real-time data collection in synchronization with experiments to provide quick data access and extend the management scope to other instruments in the MLF.

For data access, the basic development of the web portal has been completed. We will begin a trial of the web portal and remote access from outside the facility with a limited number of users. However, some issues regarding security need to be addressed before a full-scale operation can begin. By addressing these issues, we will start a full-scale operation for data access later this year.

5. Conclusion

We successfully improved MLF EXP-DB and enhanced its availability and scalability toward achieving a full-scale operation of the system and facility in the future. The current system is a scaled-out, redundant distributed configuration. In addition, we developed a flexible data search function in a web portal. A user can easily and quickly search for data required for analysis from a large amount of data using this function.

References

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[3] http://www.i4s.co.jp/rcm/rcmabs.html (in Japanese).