Applications of the differential events reading method at MLF, J-PARC

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Abstract. An event recording method for data acquisition for neutron scattering and its analysis provides a lot of benefits for the measurement of time-resolved and time transient phenomena. Almost all instruments installed in the Materials and Life Science Experimental Facility (MLF) at J-PARC have adopted this method since the first beam came and have achieved good results. On the other hand, our treatment of event recorded data leaves room for improvements and developments to achieve more effective utilization. This paper introduces one of the applications of the event recording method to achieve the pseudo real-time data treatment in MLF in a simple way.

1. Introduction
An event recording method for neutron scattering measurements has been adopted widely at a lot of neutron instruments in the world because this method has advantage for time-resolved measurements and response phenomena in a sample under an external field. The Materials and Life Science Experimental Facility (MLF) also has adopted an event recording method as a standard data acquisition system (DAQ), which is realized by DAQ middleware [1], since the first neutron beam was produced. The DAQ middleware system can gather neutron detection events from the board connected to each detector, i.e. ³He-position sensitive detector (PSD), 2D- or 1D- scintillation counter, N₂ beam monitor and so on, to store the data as binary files. Now the event recorded information comprises not only a neutron or muon detection but also conditions of sample environment and instrument devices in MLF, for example an orientation of sample stage goniometer, temperature, choppers, beam narrower (beam slits) and so on. The neutron detection event in MLF includes the time of flight and the position of the neutron detection. This method gives MLF users higher flexibility and efficiency on the measurement and analysis.

The first step to treat event recorded data is to convert events to histogram data with a unit conversion for easy understanding and to do a variety of corrections on the data, so-called data reduction. At almost all instruments in MLF, “Manyo Library” [2,3] and “Utsusemi” software [4] are utilized to do such data reduction steps. The Manyo Library is a software framework for handling data containers with operations and developing data reduction software. The Utsusemi, which is based on
the Manyo Library, is a set of software to analyze and visualize event recorded data with a graphical interface [Fig.1]. Especially, the Utsusemi successfully contributed to enable the multi-Ei method in inelastic scattering for the first time in the world by its flexible data reduction [5].

The data reduction functions in Utsusemi are developed under the assumption that they are to be carried out with a static data file after its data acquisition finishes. This means that the histogram conversion code reads data files from the beginning to end for each time. On the other hand, users require strongly a “real-time analysis and visualization” to see and check the obtained data during measurements, because users want to confirm the current measurement conditions frequently and to decide the next condition as soon as possible. In this case, as the data files are accessed from both the DAQ middleware and the data reduction code for a long time, the risk of trouble such as file destruction, becomes higher. In addition, it takes a long time to read data files from the beginning.

To resolve these issues, we produced a kind of monitoring system which observes the current event recorded data files and periodically executes data reduction only on differential events.

2. The event treatment and the concept for developments
To realize ‘real-time’ data reduction and visualization, we have considered that we should make the event recording method practical to use. So we decided to utilize the differential events in the event data files produced continuously by a DAQ system. Therefore, this system is not a true ‘real-time’ treatment but a pseudo one. In this section, we show the format and the treatment of event data in MLF and the concept of the development of the differential events reading method.

2.1. Event recorded data format and treatments
The events used in MLF are classified into several types, i.e. a neutron detection event, T0 event which indicates the origin of time-of-flight with its identification number, an absolute time event and a common electrical signal event. A neutron detection event includes the internal position information on the detector and time-of-flight, but event format for each detector, for example between $^3$He-PSD and a scintillation counter, has a slightly different characteristic. Especially since $^3$He-PSD event includes the pulse height values of amplified electrical signals from detectors as position information, we distinguish events from electrical noise by pulse height filtering on histogram conversion. This function is very effective for analysis of the data including gamma ray background from instrument devices and sample by incident neutrons. Neutron detection events are produced from an electronics board connected with detectors, which are developed by the DAQ group in MLF. One board groups all events of several detectors into one event stream to be gathered by the DAQ middleware to save as the
event data files. Each event data file includes identical T0 events and absolute time events for keeping time synchronization between files.

On converting event data to histogram format in Utsusemi, the time-of-flight values included in events can be converted to another unit, i.e. energy, wavelength, momentum transfer and energy transfer, using detector positions with any range given by users. In addition, software enables extraction of events in the given absolute time region to make a histogram simply. A period of the neutron production at the source of MLF is a typical unit used for a time slicing, 25 Hz, which is called a frame. We generally adopt a frame as the time unit because wide energy neutrons are usable in this period. For speeding up reading and treating event data files, the Utsusemi code divides the event stream from the data file into the unit of frames to be used for data reduction with multiple processes. To divide the event stream effectively, we prepare a bookmark list for T0 events inside a file, called T0 index information, which records the number of events from the beginning of a file to each T0 event and its absolute time as shown in Fig.2. These bookmark T0 indexes are used not only to distribute each divided data stream to multiple processes for off-line reading of data files but also to slice by a given time range with high speed. T0 index information can be made from each event data file and can be reused once it is made. For instruments using Utsusemi in MLF, their DAQ system also includes the software module to make T0 index information directly from streaming of events and save them as a file.

2.2. The concept to realize a pseudo ‘real-time’ data reduction

To realize a pseudo ‘real-time’ data reduction, we produced the differential events reading method which observes the event data files periodically to read the differential part of the files updated and convert them to histogram format containers incrementally [Fig.3]. Reading differential events from the file is easy to introduce into the existing software at beamlines because it has little effect on the DAQ system and software environment already in use.

At first, the software allocates and keeps the histogram area with given information by a user on the memory in PC and starts the observation on the updated data file. The target files of the observation are not event data files but T0 index files to reduce the access to the storage. If updated T0 index files are found, the software reads the updated part of T0 index to extract the differential events stream from the files. If there is a
disagreement between the T0 information and the actual event data file by a different output timing from the DAQ system, the software adjusts the T0 information for the actual situation. The extracted differential events are converted incrementally to histogram format containers in the memory to be used for the data reduction steps. As this histogram format is the same as that used at the off-line data reduction and visualization, the existing code can be utilized directly. Users can clear the incremental counts of histogram in the memory for each observation to visualize the differential data like a current data monitoring. This method is very convenient but does not contribute to the time cost for the data reduction steps. In addition, if users want to change the axis unit or the ranges of the histogram, the software must delete the histogram in the memory area to read event data files from the beginning again. We understand that there are still risks that the data on a the storage is damaged but the risk becomes small.

3. Applications in MLF

Our differential event reading method has several features. One is the processed speed become higher because of the decrease of the amount of events to be treated at a time. Second is the flexibility of the data observation, which enables users to decide an interval time to obtain the differential events and to convert events to histograms with counting not only incrementally but also differentially, i.e. counts summation from beginning or only differential events in the interval period. The third is that it is a simple task to introduce this differential data reduction by only replacing the program to read event data with this software module.

This method has already been introduced in several instruments in MLF. One example is a neutron beam monitor with visualization. This simple software creates incremental histogram data by reading the differential events and plots it with a 1D plotter. This system is installed at BL15, BL17 in MLF [Fig.4(a)]. The other case is where many detectors must be treated. At BL11, in which over 300 PSDs are installed, users want to watch the ‘real-time’ incremental data which the data reduction process finishes [Fig.4(b)]. The third case is to be used in the inelastic beamlines. In the inelastic scattering measurements on a single crystal, we have many opportunities for measuring a crystal rotated over a wide angle to obtain the whole excitation in the energy-momentum space as a map. Recently we successfully produced the system of 4D mapping measurement not by a step-by-step change of a single crystal sample orientation but by a continuous rotation of a sample with a pseudo real-time visualization for the incremental data during the measurement, as shown in Fig.4(c). In this system, orientation information is recorded as events with a time stamp the same as one of the neutron detections events. We added the new function to the differential data reduction software to divide neutron events by orientation information at the detection time for each angle. We do not describe the details of this result in this paper.

![Figure 4](image)

**Figure 4.** The screen shots of GUI for applications using the differential event reading method. (a) is the beam monitor, (b) is ‘real-time’ data reduction of many detectors and (c) is the 4D space mapping measurement by the continuous rotation of a single crystal.
4. Future plans
The basic system for the differential event reading method is ready, however this is introduced in only a few beamlines because of the lack of easy-to-use graphical interface to execute each data reduction step with this method. Therefore, we continue to develop these. On the other hand, there is an intense progress of the technology treating a message queue recently. We also consider that this technology of an asynchronous communications protocol should be used for our data acquisition system and the data reduction, especially for monitoring current measurement data and device conditions. We have already started an attempt to import the message queue system into our DAQ system and to apply it to the data reduction part in Utsusemi. It is not difficult to replace the differential event conversion with a queue protocol as mentioned above.

5. Summary
We introduced, in this paper, how to treat event recorded data in MLF and successful use for differential event reading method as a common data monitoring system in MLF. We achieved the situation that users can get full analyzed data just after finishing their measurement. However, this system leaves room to be upgraded with the new technology and should be utilized for more beamlines. We will continue the developments for these purposes.

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