BYACO ecosystem for innovative online operation of BigRIPS experiments with seamless connection to comprehensive analysis

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Device and detector settings can be optimized online by using information based on histograms created in an online analysis. The particle identification (PID) of a radioactive isotope (RI) beam is often necessary to check the detector response. PID analysis is one of the most important issues, especially for RI-beam tuning, to produce the required RI beams at the BigRIPS fragment separator.[1)] RI-beam separation and PID are difficult for heavy or low-energy RI beams, since the charge state of the RI beam could be different from that of the fully-stripped ion and/or the accuracy of the energy-loss prediction may be insufficient. For the PID analysis of RI beams having different charge states from that of the main RI beam or occasionally having any charge states, comprehensive analyses including fine calibrations and consistency checks among different RI-beam settings were performed after the experiments.[2–4)] In order to operate the BigRIPS separator for these types of RI beams, it is desirable to perform the comprehensive analysis online.

The BeYond Analysis, Control, or Operation alone (BYACO) ecosystem is being developed for the innovative online operation of BigRIPS experiments by connecting the comprehensive analyses seamlessly with other components such as device and detector controls and data acquisition systems. BYACO connects each component using REST and WebSocket application programming interfaces (APIs) by applying rapidly evolving web technologies, as shown in Fig. 1. The BYACO main server is built using Node.js[5)] and distributes a single-page application in the web browser, which is written using the React JavaScript library.[6)] The main server handles requests as the proxy server. Other servers return a response for the forwarded request and can generate an event-driven request to others. To share information in real time, push notifications are sent using WebSocket technology. A client or each server sends a list of interest to the main server. When each server detects updates, they are sent to requesting clients through the main server.

The data analysis is divided into real-time and comprehensive analyses, as shown in Fig. 1. The raw-data calibration and PID reconstruction are processed in the real-time analysis. The obtained variables including the raw data are stored as a TTree object in ROOT.[7)] When waveform data are taken in the future, high-throughput processing will be necessary before the real-time PID reconstruction. For the comprehensive analysis, a ROOT-based graphical user interface (GUI) analyzer for the BigRIPS experiment (BigROOT) was developed. Macro programs used in the offline analysis are implemented as selectable tools working on PROOF-Lite in ROOT,[7)] which provides functions for the event loop as well as histogram drawing and final analyses. The GUIs to perform simple curve fitting and to make projection and profile histograms have been implemented.

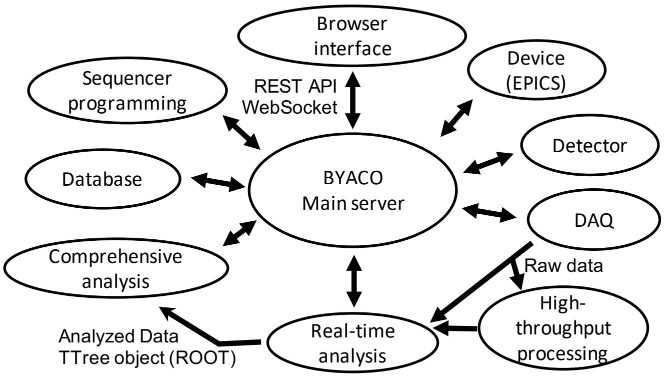

Fig. 1. Conceptual diagram of the BYACO ecosystem. The REST and WebSocket APIs are used for the communication. The sequencer programming is for sequential operations such as automatic RI-beam tuning.

The sequential operation consisting of the data acquisition, analysis, device control, etc. needs to await a response or status change. At present, the sequence of these asynchronous tasks, which are performed by referring to many types of information, are managed using the Redux and Redux-Saga libraries[8,9)] on Node.js. As the first application of the sequential operation, the automatic focusing and centering of RI beams were tested online in 2020 with great success.[10)]

References
1) N. Fukuda *et al.*, Nucl. Instrum. Methods Phys. Res. B **317**, 323 (2013).
2) N. Fukuda *et al.*, J. Phys. Soc. Jpn. **87**, 014202 (2018).
3) T. Sumikama *et al.*, Nucl. Instrum. Methods Phys. Res. B **463**, 237 (2020).
4) T. Sumikama *et al.*, Nucl. Instrum. Methods Phys. Res. A **986**, 164687 (2021).
5) Node.js, `https://nodejs.org/`.
6) React, `https://reactjs.org/`.
7) R. Brun, F. Rademakers, Nucl. Instrum. Methods Phys. Res. A **389**, 81 (1997), `https://root.cern.ch/`.
8) Redux, `https://redux.js.org/`.
9) Redux-Saga, `https://redux-saga.js.org/`.
10) Y. Shimizu *et al.*, in this report.

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