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STATUS OF ONLINE MODEL DEVELOPMENTS FOR BESSY II

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Abstract

Digital twins have emerged as a powerful tool for monitoring and optimizing complex systems, including synchrotron light sources. This paper describes the development of a digital twin for BESSY II and MLS, two synchrotron light sources, which allows for real-time monitoring of the machine status and easy integration of online analysis while measurements are taken. The digital twin is designed to provide accelerators with commissioning predictions and feedback capabilities, and offers greater flexibility in configuring the modelling part combined with ease of adding new features. To enable the various components developed in EPICS, Python, C, and C++ to work together seamlessly, a microservice design is adopted, with REST API services providing the interfaces between the components. End user scripts are implemented as REST API services, allowing for better data analysis and visualization. The paper also describes the integration of Dash and Plotly for enhanced data comparison and visualization. Overall, this workflow provides a powerful and flexible solution for managing and optimizing BESSY II digital twins, with the potential for further customization and extension to upcoming machines. The digital twin is also considered important for the design of complex systems and can serve as a natural interface for machine learning and AI approaches.

INTRODUCTION

Digital twins are virtual representations of physical systems that enable real-time monitoring, analysis, and optimization of complex processes [1]. This technology has gained popularity in recent years for its ability to improve efficiency, reduce costs, and enhance safety in a variety of industries, including aerospace, smart cities, healthcare, automotive, and energy [2]. Digital twins have the potential to be an effective tool for modeling and monitoring the behavior of complex systems in the field of synchrotron light sources, and there is growing interest in their application in this area.

According to the European Synchrotron Radiation Facility (ESRF), synchrotron light sources are large-scale research facilities that generate intense beams of light for use in a wide range of scientific and industrial applications, including material science, biology, and drug discovery. These facilities are incredibly complex, with thousands of components and subsystems that must work together seamlessly to produce high-quality light beams. Digital twins provide a way to model and monitor these systems in real-time, allowing operators to optimize performance, troubleshoot problems, and minimize downtime.

Synchrotron light sources are large-scale scientific facilities that generate intense beams of light for use in a wide range of research fields, including material science, biology, and environmental science. These facilities typically consist of a linear accelerator, a booster ring, and a storage ring, where electrons are accelerated and circulated at high speeds to produce synchrotron radiation. The design and operation of these facilities are highly complex, with thousands of components and subsystems that must work together to produce high-quality light beams [3].

The Experimental Physics and Industrial Control System (EPICS) is a widely-used software framework for control systems in scientific facilities, including synchrotron light sources. EPICS provides a standard interface for interacting with hardware devices and data acquisition systems, as well as a range of tools for monitoring and analyzing system performance. EPICS has become the de facto standard for control systems in many scientific facilities, due to its flexibility, scalability, and reliability [4].

Microservice design is a software architecture pattern that has gained popularity in recent years for its ability to create flexible, scalable, and modular systems [5]. Microservices are small, independent services that work together to provide a larger, complex application. Each microservice has a specific functionality, and communicates with other microservices through well-defined APIs. This approach allows for greater flexibility and agility in software development, and can lead to more robust and maintainable systems. The use of microservice design in synchrotron light sources allows for greater interoperability between components developed in different languages and frameworks, and can improve overall system performance and reliability.

This paper describes the creation of a digital twin for BESSY II and MLS (Metrology Light Source), two synchrotron light sources that have been in operation for a significant period. To achieve this, we utilized standard EPICS as the interface and utilized MongoDB in JSON format to store the machine structure. We also employed REST APIs to retrieve data from the database and Python scripts to assist in the commissioning process. The implementation includes the use of REST API services and microservice design to enable seamless communication between the various components of the system. As illustrated in Fig. 1, the diagram depicts the communication flow between the REST API and Calculation Engine in the digital twin.

We also describe the integration of Dash and Plotly for enhanced data comparison and visualization. The digital twin provides a flexible and efficient solution for monitoring and optimizing synchrotron light sources, with the potential for further customization and extension to upcoming machines.

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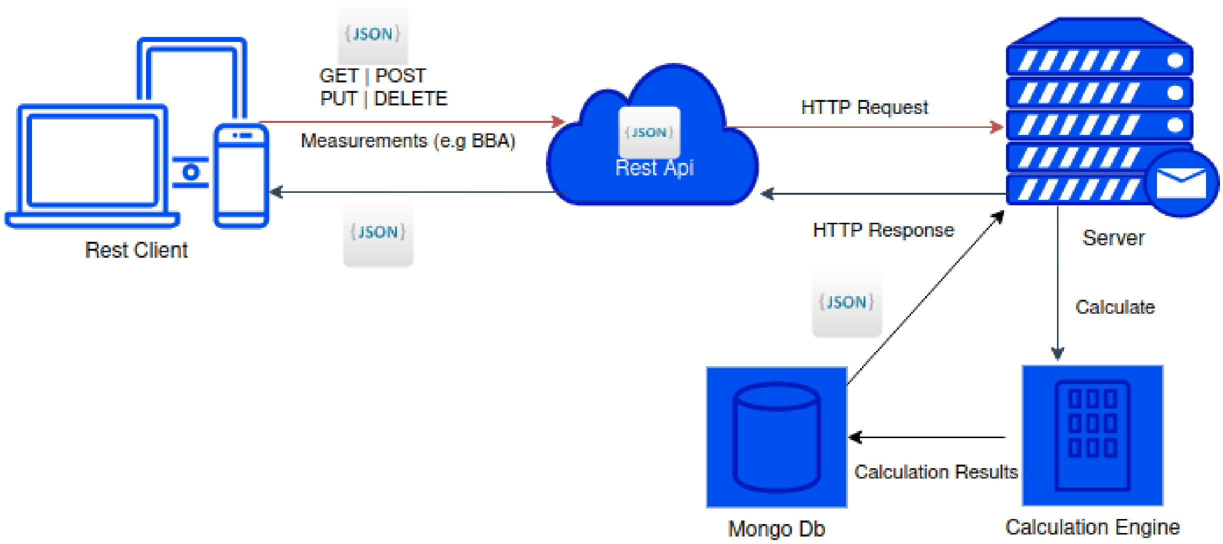

Figure 1: Interfacing REST API with calculation engine in the digital twin.

DIGITAL TWIN IMPLEMENTATION

In this section, we describe the development of the digital twin for BESSY II and MLS, which is based on the EPICS control system and utilizes a microservice architecture. The digital twin provides a real-time model of the synchrotron light sources, which allows operators and researchers to monitor and control the machines more effectively. Standard EPICS is used as the interface for our implementation, which provides a proven and reliable framework for control systems in scientific facilities.

To store the machine structure in a flexible and easily accessible way, we decided to use MongoDB as our database, with the machine structure stored in JSON format. This allows for easy updates to the machine structure, and provides a more flexible alternative to traditional lattice files. The machine structure modeling is done using the open-source toolkit Bluesky and Ophyd, which provides a flexible framework for defining and executing experiments. This enables us to describe commissioning tasks in a flexible fashion, including the ability to add online analysis while measurements are taken.

To enable communication between the various components, we use REST API services as the interface. This allows for seamless communication between components developed in different languages and frameworks, as each microservice has a specific functionality and communicates with other microservices through well-defined APIs. End user scripts will be developed as REST API services, this will enables them to access the digital twin more easily and effectively.

One of the advantages of using REST API services is the ability to integrate better data analysis and data visualization tools, which can be used to provide more advanced and informative data to the end user. In our implementation, we have integrated the open-source data analysis and visualization libraries Dash and Plotty, which provide advanced tools for data analysis and visualization. These tools enable operators and researchers to more effectively analyze and compare data from different experiments, and to identify patterns and trends that may not be immediately apparent from raw data.

Dash is a Python framework for building web applications, while Plotly is a data visualization library that can be used with a variety of programming languages. By integrating these tools with the digital twin, we were able to provide end users with a range of benefits. Firstly, the use of a web-based interface enables easy access to the digital twin from any device with an internet connection. This allows end users to monitor the status of the machine and analyze data in real-time, regardless of their physical location.

Secondly, the integration of Dash and Plotly enables enhanced data comparison and visualization. Dash provides a framework for building interactive web-based dashboards, which can be used to display data in a variety of formats, including tables, graphs, and maps. Plotly provides a wide range of customizable data visualization tools, including scatter plots, line charts, and histograms, which can be easily integrated with Dash applications.

As depicted in Fig. 2, the diagram illustrates the intricate data flow and integration within the BESSY II digital twin architecture. It showcases the interconnectedness of various components, including BESSY II, EPICS, calculation enginer, MongoDB, commissioning scripts, and data visualization tools. The diagram highlights the communication pathways and the seamless exchange of data between these components, facilitating the efficient functioning of the digital twin. It exemplifies how EPICS serves as the interface for interacting with the SLS machines, with data being stored in MongoDB in JSON format. Commissioning scripts leverage the REST API services for enhanced data analysis and visualization, ultimately contributing to the comprehensive monitoring and optimization of the SLS system. This diagram provides a visual representation of

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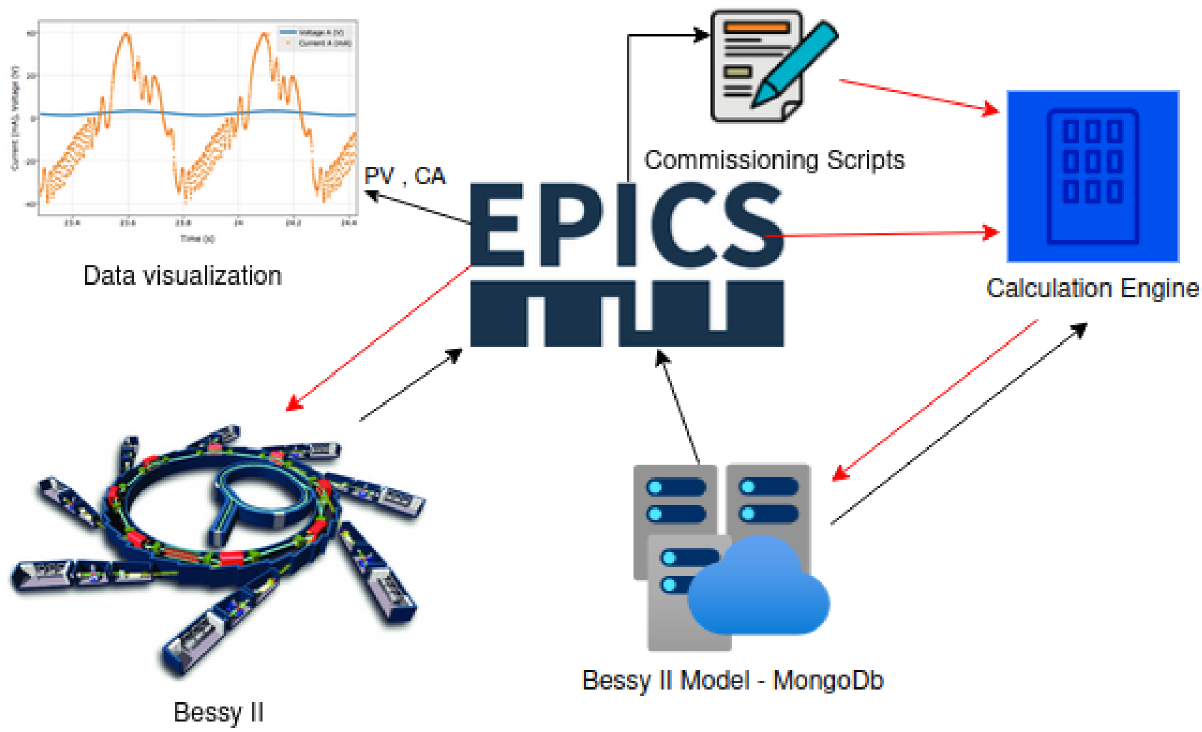

Figure 2: Interfacing REST API with calculation engine in the digital twin.

the integration and data flow within the SLS digital twin, emphasizing the interconnected nature of the components involved.

Overall, the digital twin implementation for BESSY II and MLS will provide a flexible, modular, and scalable architectures that can allow for easy integration of new components and features. The use of standard EPICS, microservice design, and REST API services provides a robust and reliable framework for control systems in scientific facilities, and enables more effective monitoring and control of the synchrotron light sources.

END USER SCRIPTS

The implementation of end user scripts as REST API services revolutionizes the interaction between end users and the digital twin, offering significant benefits for data analysis and visualization. With this approach, end users experience a seamless transition as they leverage REST API services to access and interact with the digital twin. This change empowers them with enhanced flexibility and efficiency in performing tasks specific to their needs.

By transitioning end user scripts to REST API services, users gain greater control over their data analysis and visualization workflows. The integration of REST APIs enables seamless connectivity between the scripts and other components of the digital twin, including data analysis and visualization tools. This integration enables end users to effortlessly access and analyze data, conduct advanced analyses, and create dynamic visualizations.

Moreover, the shift to REST API services facilitates collaboration and knowledge sharing among end users. Scripts can be easily shared and utilized by other researchers and operators, fostering reproducibility of experiments and analyses. The standardized interface provided by REST APIs ensures compatibility and ease of integration with various components of the digital twin, irrespective of the programming language or framework used to develop the scripts.

CONCLUSION

In summary, the development of a digital twin for BESSY II and MLS synchrotron light sources using EPICS, microservice design, and REST API services will greatly enhanced system monitoring and optimization. The integration of EPICS and the adoption of a microservice architecture will enable seamless communication between components, improving interoperability and reliability. The digital twin provides a flexible and scalable solution for managing and optimizing synchrotron light sources, with potential for further customization and extension.

To conclude, the digital twin implementation will revolutionize system monitoring and optimization. The implementaion of end user scripts as REST API will empower users with advanced data analysis and visualization capabilities. Overall, the digital twin presents a flexible and scaleable solution for effectively managing and optimizing synchrotron light sources.

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