Developement of Digital Twins of Scientific Equipment and Systems for MegaScience-class Installations.

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11.10.2023

Abstract

Keywords: Keyword1, Keyword2, Keyword3, Keyword4, Keyword5

1 Introduction

In the realm of MegaScience-class installations, the concept of digital twins has emerged as a transformative technology, offering unprecedented opportunities for enhancing the design, operation, and maintenance of scientific equipment and systems. A digital twin is a virtual representation of a physical asset that enables real-time prediction, optimization, monitoring, controlling, and improved decision making in scientific equipment and systems [1]. This technology is not just a theoretical construct but a practical tool that has been increasingly applied in various fields, including manufacturing, healthcare, and now, in scientific research facilities.

The development of digital twins for scientific equipment and systems involves creating a framework that provides monitoring and evaluation capabilities for equipment involved in manufacturing and experiments [2]. This framework is crucial for MegaScience-class installations, where the complexity and scale of equipment and experiments demand precise and real-time monitoring for optimal performance and safety.

Moreover, digital twins serve as a new normal form for solving problems in a changing context, such as in the case of product quality monitoring, as highlighted by Zhang et al. (2020) in their study on a product quality monitor model with the digital twin model [3]. This adaptability is particularly valuable in the dynamic environment of MegaScience installations, where equipment and systems must consistently operate at peak efficiency under varying conditions.

The integration of computational models, sensors, learning, real-time analysis, diagnosis, and prognosis in digital twins supports engineering decisions related to specific assets [4]. This comprehensive approach is essential for the intricate and high-stakes nature of scientific research, where even minor miscalculations or malfunctions can lead to significant setbacks.

In summary, the development of digital twins for scientific equipment and systems in MegaScience-class installations represents a significant leap forward in the management and operation of complex scientific infrastructure. By leveraging the power of virtual modeling, real-time data analysis, and predictive capabilities, digital twins offer a pathway to more efficient, reliable, and advanced scientific research.

2 Literature Review

In the evolving landscape of mega-science projects, the integration of digital infrastructure and remote access capabilities has become increasingly crucial. A seminal paper in this domain is [5], which offers a comprehensive analysis of the role and implementation of digital twins and digital traces in mega-science facilities. This paper is instrumental in understanding the shift towards remote accessibility in scientific research, particularly in the context of large-scale, international scientific collaborations.

Balyakin et al. emphasize the necessity of minimizing the physical presence of researchers at scientific facilities, a concept exemplified by the Borexino project's use of an independent data collection system. This approach not only facilitates remote data acquisition but also significantly reduces the logistical and financial burdens associated with travel to these facilities. The paper further delves into the development of appropriate digital infrastructure, highlighting the need for new digital elements such as data centers and advanced processing algorithms. This infrastructure is crucial for the seamless integration of mega-science installations into existing e-Infrastructure, thereby enhancing the efficiency and scope of scientific research.

Moreover, the paper discusses the legal and methodological frameworks required to support the operation of scientific facilities in remote access mode. This aspect is critical in addressing the challenges posed by data security, intellectual property rights, and the nuances of international scientific cooperation. The authors also underscore the importance of engineering personnel in maintaining and ensuring the functionality of remote access modes, pointing to the need for specialized skills and resources in this area.

A key contribution of this paper is its exploration of the concept of e-Infrastructure, particularly its emergence and evolution within the European Union. The European Open Science Cloud (EOSC) and the Go FAIR initiative are presented as pivotal developments in this field, demonstrating the EU's commitment to digitalizing scientific research and fostering a more interconnected scientific community. The paper posits that while natural sciences are the initial beneficiaries of e-Infrastructure, its most significant impacts are likely to be seen in the field of humanities, necessitating the development of new assessment methods and legal solutions.

In summary, ”Digital Twins vs Digital Trace in Megascience Projects” by Balyakin et al. is a foundational paper that provides valuable insights into the digital transformation of mega-science facilities. It not only addresses the technical and infrastructural aspects of this transformation but also considers the broader implications for scientific research, policy, and international collaboration. The paper's exploration of digital twins and digital traces offers a nuanced understanding of modern data processing techniques, making it a crucial reference for researchers and policymakers involved in the planning and operation of large-scale scientific installations.

3 Research Setup

4 Methodology

5 Preliminary Results

6 Conclusion

7 References

[1] A. Rasheed, O. San, and T. Kvamsdal, "Digital twin: Values, challenges and enablers from a modeling perspective," *IEEE Access*, vol. 8, pp. 21980–22012, 2020.

[2] J. Duan, T.-Y. Ma, Q. Zhang, Z. Liu, and J. Qin, "Design and application of digital twin system for the blade-rotor test rig," *Journal of Intelligent Manufacturing*, vol. 34, pp. 753–769, 2021.

[3] S. Zhang, C. Kang, Z. Liu, J. Wu, and C. Ma, "A product quality monitor model with the digital twin model and the stacked auto encoder," *IEEE Access*, vol. 8, pp. 113826–113836, 2020.

[4] T. Ritto and F. Rochinha, "Digital twin, physics-based model, and machine learning applied to damage detection in structures," *Mechanical Systems and Signal Processing*, vol. 155, p. 107614, 2021.

[5] A. Balyakin, N. Nurakhov, and M. V. Nurbina, "Digital twins vs digital trace in megascience projects," *Information Technology and Systems*, vol. 1330, pp. 534 – 539, 2021.