Data Mining in Industrial Applications of Digital Twins

Special track along with the Fifteenth International Conference on Pervasive Patterns and Applications, PATTERNS'23
June 26 - 30, 2023 in Nice, France

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***Abstract*—This editorial paper summarizes three presentations from the session of the special track "Data Mining in Industrial Applications of Digital Twins". These presentations and research papers provide insights into three different aspects of Data Mining and Digital Twins as follows:**

1) **Digital Twins as methods to asses and protect digital privacy and its potential threats.**
2) **The industrial IT landscapes for building Digital Twins using an Industrial Metaverse.**
3) **Knowledge graphs in automotive manufacturing as a base for a Digital Twin development.**

We show that these topics are of high relevance for practitioners as well as researchers, and that the following contributions offer insights and solutions for important questions regrading the state-of-the-art of applied Data Mining and Digital Twins.

***Index Terms*—Cyber-Physical Systems, Digital Twin, Industrial Metaverse, Knowledge Based Systems, Privacy, Production Engineering, Social Networks, Virtual Commissioning**

I. Introduction

In the past few years, great advances in the field of Data Mining have been made. Nevertheless, best practices developed by the research community are still not widely implemented and applied in industry applications. This is the result, because methods are often developed, tested, and published for research purposes by, e.g., using carefully selected and cleansed data sets and by discussing an implementation only in very specific test scenarios. In addition, an implementation is often hindered by industry-specific challenges, in particular data availability and quality, scalability of methods for data lakes in Internet of Things applications, the necessary expertise and change management, and high implementation costs.

Lately, the development and the rollout of Digital Twins across different industries enable new possibilities for implementing Data Mining methods on a bigger scale and with higher economic impact on real world scenarios. Furthermore, Data Mining methods are an integral part of the success of Digital Twins in practice. For a successful implementation of Data Mining methods in Digital Twins, current challenges must be overcome by applied research extending state-of-the-art methods to tackle the real-world requirements of industrial applications. Thus, we want to discuss current challenges of an application of Data Mining during the development of Digital Twins and create applied solutions for upcoming tasks.

II. Submissions

The core idea of a Digital Twin as a virtual representation of a physical system but also a functional entity on its own was first introduced in 2002 by Grieves [1]. There is a steadily growing amount of research about Digital Twins mostly in the field of manufacturing. However, the Digital Twin concept is today more versatile and applied in different scenarios and domains. Bäumer et al. (2021) proposed the Digital Twin concept as a method to track the online vulnerability of individuals regarding privacy issues [2]. In these scenarios, the Digital Twin represents a real person instantiated by the available online information. Thus, this Digital Twin is capable of measuring threats to the digital privacy of individual.

Within this field of research, the in this track presented paper by Schultenkämper and Bäumer (2023) show that a Digital Twin of the online activities of a person can be created by linking multiple data sources and data types using methods from natural language processing, computer vision, and ontological modeling. Furthermore, Schultenkämper and Bäumer (2023) introduce two datasets for the future training and improvement of these models. Thus, their contribution lays the foundation for future research with focus on the evaluation of Digital Twin capabilities in mitigating privacy threats. This also enables a more in-depth discussion of ethical and legal implication of this application [3].

In the last few years, the topic of the Metaverse emerged from the field of Digital Twins to enable an immersive collaboration among all participants. This includes virtual, mixed, and augmented virtual reality. The Metaverse provides an immersive workspace within a configuration layer of Cyber-Physical Systems and is as such considered the Digital Twin

of this workspace [4]. Therefore, use cases exist in the field of industrial product design, production, application, and service. Furthermore, the virtual reality capabilities enable use cases with strong interaction with the real world, such as industrial inspection, auxiliary maintenance, and practical training [5].

For the application of Industrial Metaverse solutions, the IT landscape of a manufacturing company must be adjusted for the specific requirements of such complex systems. Lüdemann-Ravit and Heieck (2023) evaluate the possible options for the set-up of an enterprise IT architecture and provide a target solution which enables a comprehensive Industrial Metaverse. Furthermore, Lüdemann-Ravit and Heieck (2023) demonstrate how a possible roll-out of the IT architecture towards the target solution can be conducted and provide a road-map over the different options [6].

As a foundation for Digital Twins, knowledge graphs are discussed as enablers and source for contextual and semantically enriched information. Thus, knowledge graphs drive the development of Digital Twins within different industry sectors [7]. Knowledge graphs are defined as applications which acquire and integrate information into an ontology and in addition provide a reasoning engine to derive knowledge about the underlying systems [8]. Knowledge graphs are particularly relevant in the current development of Digital Twins of the assembly lines within the automotive industry.

To compare the requirements for the development of knowledge graphs from the body of literature and by practitioners, Spoor et al. (2023) conduct a systematic evaluation of the important and relevant criteria within automotive manufacturing based on academic research and provide in addition insights from expert interviews from the automotive industry. Spoor et al. (2023) detect the aspects of real-time monitoring, predictive maintenance, and data governance where requirements from practitioners and literature differ [9]. This enables future research and knowledge graph developers to create more targeted solutions for the automotive industry.

III. Conclusion

The contributions of this special track enable solutions for real-world challenges of industrial applications such as an IT landscape roadmap for the development of an Industrial Metaverse. Also, a foundation is given for the targeted development of systems and application of Digital Twins and knowledge graphs in manufacturing. Furthermore, the contributions show the wide range of Digital Twin concepts in manufacturing and the automotive industry as well as in digital threat detection. For the field of digital threat detection, two useful datasets for future research projects are evaluated and presented.

Thus, the contributions are successfully providing solutions, examples, and use cases for industry-specific challenges and therefore, are extending the state-of-the-art methods of Digital Twins and Data Mining in real-world industrial applications. This should enable future research in Data Mining and Digital Twins to take real-world scenarios into account. In addition, further research topic are already proposed by the authors.

Acknowledgment

A special thanks to the organizers of the conference for the reception of this special track as part of the conference program. Also, we thank the reviewers for their valuable comments and quality assessment of the contributed papers.

Concluding, we thank all contributing authors of this track for the interesting and important contribution towards applied Data Mining and Digital Twins across multiple domains.

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