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A sustainable approach to smart manufacturing: The IndustriSphere digital twins initiative

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Abstract Modern industrial production faces several critical challenges, including inefficiency, lack of adaptability, and unsustainable practices. Traditional manufacturing systems struggle with high operational costs, suboptimal resource utilization, and limited capabilities for predictive maintenance, leading to frequent downtime and increased environmental impact. Moreover, existing production processes often lack integration with advanced technologies like IoT and AI, restricting real-time monitoring and innovation potential. The IndustriSphere initiative pioneers a sustainable shift in manufacturing by applying digital twin technology to optimize industrial processes. Integrating IoT, AI, 3D scanning, and augmented reality, it enhances real-time monitoring, predictive maintenance, and resource efficiency. Validated at B&T Composites, the project combines academic expertise with practical implementation, advancing Industry 4.0. Through lifecycle sustainability analysis and immersive digital models, IndustriSphere demonstrates how smart manufacturing can reduce environmental impacts while boosting competitiveness and innovation across industrial sectors.
Keywords: Digital Twins, Industrial Efficiency, Predictive Maintenance, Sustainability.

1. Introduction

Industrial production faces mounting challenges related to efficiency, adaptability, and environmental impact. Traditional systems often fall short in predictive maintenance, real-time monitoring, and energy optimization. The IndustriSphere project addresses these issues through the implementation of digital twin technology, integrating Internet of Things (IoT), Artificial Intelligent (AI), 3D scanning, and Augmented Reality (AR), to enable dynamic, real-time simulation and analysis of manufacturing processes. The integration of technologies such as artificial intelligence, augmented reality, and IoT into the development of digital twins accelerates the implementation of innovations and enables data-driven predictive maintenance and process optimization (Böhm et al., 2021).

Moreover, by fostering sustainability through lifecycle assessments and enhancing operational responsiveness, IndustriSphere represents an inclusive shift toward smarter, greener production. The initiative is grounded in academia–industry collaboration and is validated through real-world application at B&T Composites, a company that specializes in advanced composite materials, offering innovative, high-performance solutions for aerospace, industrial, and energy applications globally, located in Florina, Greece.

2. Objectives and methodology

Lately, Industry 4.0 approaches in industrial automation and digital twins have embrace technologies such as Cyber-Physical Systems and the Internet of Things (IoT), enabling the integration, monitoring, and optimization of industrial processes. This evolution signals a shift toward more dynamic and unified production and management systems, merging the physical and virtual worlds to enhance the design, monitoring, and optimization of manufacturing operations (Kaiblinger and Woschank, 2022).

The objectives of the IndustriSphere initiative focus on enhancing industrial efficiency, sustainability, and innovation through digital twin technology. Key goals include developing accurate 3D models of production environments, enabling real-time monitoring via IoT and AR, and implementing predictive maintenance using AI algorithms. The integration of advanced simulation and prediction systems into manufacturing processes, leveraging machine learning and sophisticated algorithms,

has been successfully demonstrated in several industrial sectors (Zobeiry and Poursartip, 2021).

Also, IndustriSphere aims to improve resource utilization, reduce environmental impacts through lifecycle sustainability analysis, and facilitate training and collaboration through immersive digital platforms. Ultimately, it seeks to modernize manufacturing by integrating cutting-edge technologies into practical, scalable industrial solutions.

The IndustriSphere methodology integrates advanced technologies to develop and deploy digital twins in industrial settings. It begins with 3D scanning to create high-fidelity models of manufacturing environments, which are then enriched with real-time data from IoT sensors. These models are accessible via a web-based platform and augmented reality for enhanced user interaction. Artificial intelligence and machine learning algorithms enable predictive maintenance and process optimization. Lifecycle sustainability analysis tools are embedded to assess environmental performance continuously. The system is piloted at B&T Composites to validate its effectiveness, combining academic research with industrial practice for scalable, sustainable manufacturing transformation.

3. The IndustriSphere solution

The IndustriSphere initiative adopts a holistic approach to integrating digital twin technologies into manufacturing, aiming to enhance efficiency, adaptability, and sustainability in production processes. These innovations are not solely intended to optimize internal operations, but also to strengthen competitiveness in a global market increasingly focused on digital transformation and sustainability. A conceptual mock-up of the envisioned IndustriSphere solution is illustrated in Fig. 1.

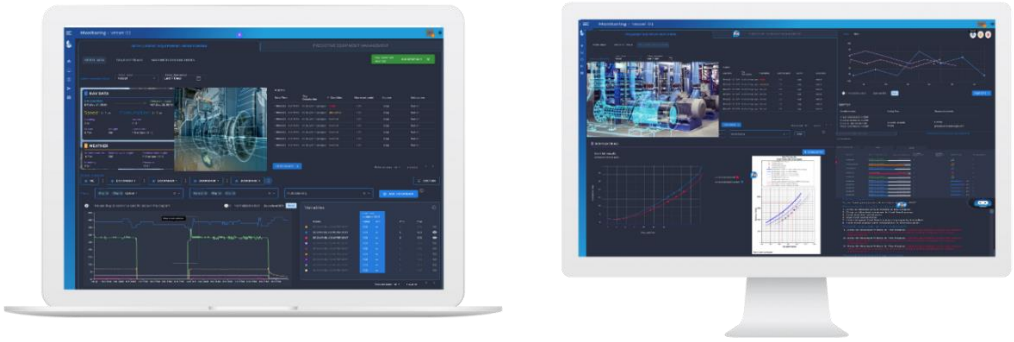

Figure 1. The IndustriSphere solution

4. Fostering sustainability through stakeholder engagement and strategic actions

Promoting awareness and engagement among all stakeholders in adopting environmentally sustainable practices is vital for the success and long-term impact of the IndustriSphere project. This will be achieved through a multi-faceted strategy; establishing clear sustainability policies to reduce the environmental footprint, organizing training workshops to inform staff and partners about sustainable practices, integrating eco-efficient technologies that improve energy use and waste reduction, disseminating best practices through publications and events, supporting Corporate Social Responsibility actions, leveraging digital tools for sustainable resource management, and committing to continuous improvement through regular updates of environmental strategies.

5. Conclusions

In conclusions, the IndustriSphere project demonstrates a forward-looking approach to modernizing industrial production by integrating digital twin technologies with advanced tools such as AI, IoT, AR, and lifecycle sustainability assessment. Its implementation highlights the potential for significant improvements in operational efficiency, predictive maintenance, and environmental performance. By bridging academic innovation with industrial application, the project sets a strong foundation for scalable, sustainable manufacturing solutions. Its emphasis on stakeholder engagement and continuous improvement ensures that IndustriSphere is not just a technological initiative, but a catalyst for long-term industrial transformation.

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