

Regeneration Ecosystem via Interoperable Digital Twins in the Circular Economy Environment

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Abstract :

Faced with today's growing environmental, economic and societal challenges, the manufacturing industry must rethink its models to incorporate the principles of the circular economy, aimed at extending product lifetimes through regeneration strategies such as reuse, remanufacturing and recycling. However, these approaches remain limited by a lack of visibility on the state of products throughout their lifecycle, and by the complexity of the decisions to be taken for their regeneration. In this context, digital twins (DTs) appear as a strategic lever, offering an interconnected vision of products, their use and associated processes. This thesis proposes to develop an interoperable ecosystem of JNs, structured around three levels: a product digital twin, enabling the evolution of a product to be tracked and anticipated throughout its life cycle; a fleet digital twin, analyzing usage trends and facilitating management at the scale of a set of products; and a process digital twin, modeling the dynamics of regeneration flows to improve decision-making. The aim is to integrate JNs into the product lifecycle, guaranteeing their interoperability to support regeneration and resource management. In this context, our project aims to design an interoperable digital twin's ecosystem that will connect and synchronize the different types of digital twins to provide insight throughout the product lifecycle and help with regeneration decisions. By guaranteeing interoperability between these digital twins, this ecosystem will facilitate the integration of data from different sources (sensors, industrial databases, IoT platforms) to offer accurate decision-making. In addition, by relying on predictive and prescriptive models, it will enable us to anticipate regeneration opportunities, reduce uncertainties linked to product flows, and adapt regeneration strategies in line with industrial constraints and market needs. Finally, this architecture will be developed in prototype and applied to several products within the framework of regeneration and the circular economy.