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On the Introduction of Semantic Digital Shadows for Enhanced Human-AI Interaction Management

In the rapidly evolving landscape of manufacturing, the integration of artificial intelligence (AI) has become increasingly important for enhanced efficiency, productivity, and innovation. However, as industries embrace the transformative power of AI, the need for a comprehensive understanding of human-AI interactions becomes increasingly evident. In this context, the concept of digital shadows emerges as a pivotal element, shedding light on the intricacies of these interactions and paving the way for a more harmonious collaboration between humans and machines.

The Teaming.AI project introduces semantic digital shadows as dynamic and semantically enriched representations of human-AI interactions within a manufacturing ecosystem. Unlike static data points, these shadows encapsulate the contextual and relational aspects of the interactions, creating a layered and comprehensive model. At the heart of this paradigm lies the utilization of Knowledge Graphs (KGs) and underlying ontologies, forming the backbone for the development of dynamic KG representations that accurately capture the intricacies of the manufacturing processes.

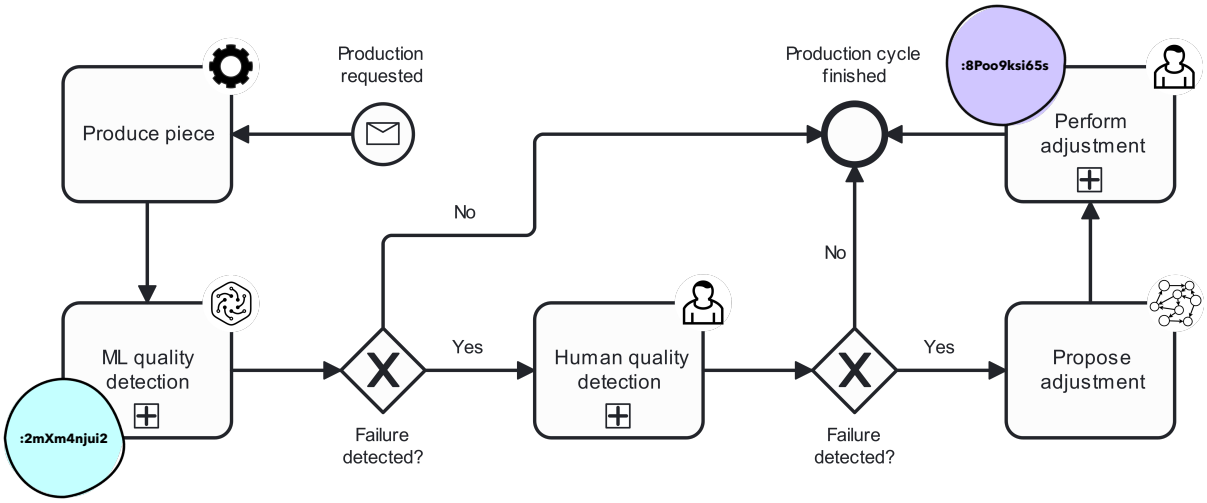

Figure 1: Sample BPMN diagram including unique IDs and corresponding KG nodes of dynamic BPMN elements.

The semantic digital shadows are directly derived from Business Process Model and Notation (BPMN) executions. These BPMN model executions serve as the orchestrating framework for human-AI interactions, ensuring a structured and optimized workflow. By leveraging KGs and ontologies within the BPMN framework, these shadows extend beyond static representations, evolving dynamically in real-

time to adapt to the ever-changing nature of manufacturing processes. Thus, executions of BPMN elements, such as activities or tasks, need to be assigned unique IDs, as displayed in *Figure 1*.

Based on the project's recent research and corresponding publications, the BPMN KG skeleton is proposed (c.f. *Figure 2*) as a static KG subgraph to semantically link dynamic BPMN element executions in a dynamic KG. This skeleton is generated once after the deployment of a BPMN model and can be re-used across all process instances of it. By doing so, the lack of dynamic digital shadows that can adapt in real-time to evolving human-AI interactions is counteracted. KGs and ontologies provide a structured framework for representing knowledge, relationships, and context, enabling the creation of dynamic shadows that can evolve alongside the complexities of manufacturing processes. This adaptability is crucial for addressing the fluid nature of human-AI interactions, allowing the system to learn from experience, adjust to changing conditions, and continuously optimize performance.

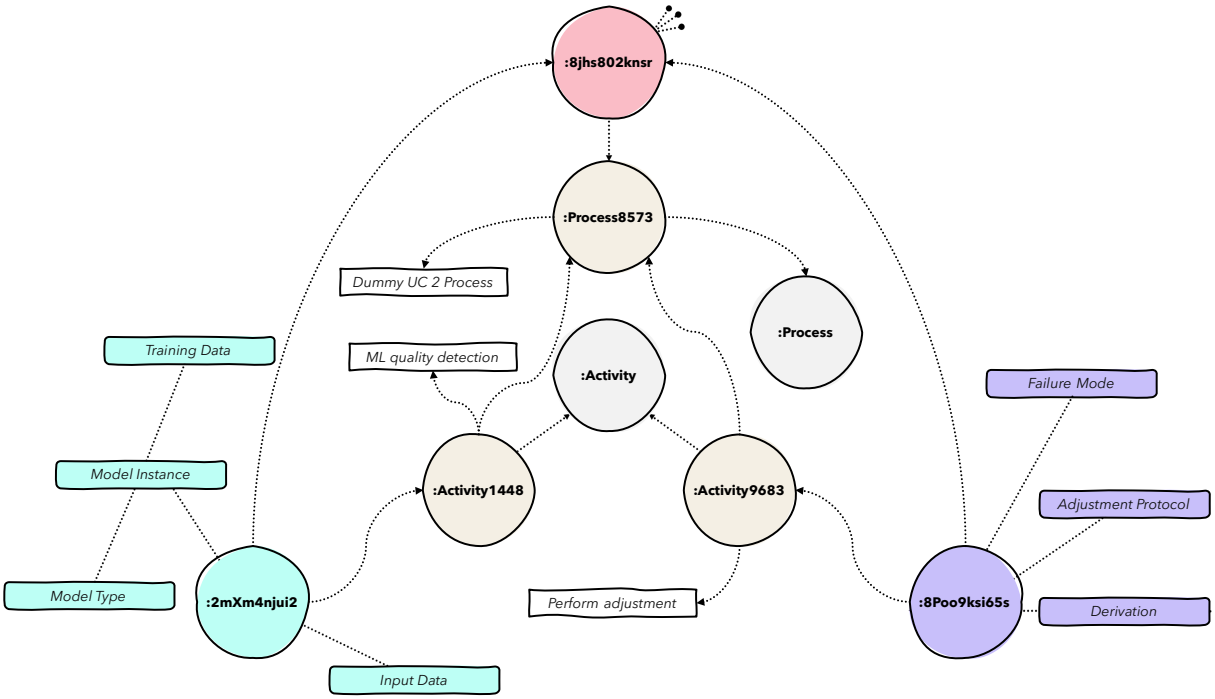

Figure 2: Static BPMN KG skeleton as a connector interface for dynamic BPMN element executions.

Moreover, the proposed semantic digital shadows serve as a powerful tool for transparency and interpretability in manufacturing processes. As AI systems become more sophisticated, there is a growing concern about the "black box" nature of these algorithms. Semantic digital shadows offer a transparent layer, enabling human operators to comprehend the decision-making processes of AI systems. This transparency fosters trust and confidence in the collaboration between humans and machines, facilitating a symbiotic relationship rather than a hierarchical one.

In conclusion, the incorporation of semantic digital shadows in manufacturing, powered by KGs and ontologies, represents a crucial step towards realizing the full potential of human-AI interactions. The dynamic nature of these shadows, coupled with their ability to adapt and provide transparency, lays the foundation for a more resilient, efficient, and collaborative manufacturing ecosystem. As research and growth navigate the future of Industry 4.0, the development, integration and semantic enrichment of sophisticated digital shadows will play a pivotal role in shaping a harmonious coexistence between human intelligence and artificial intelligence in the manufacturing domain.

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