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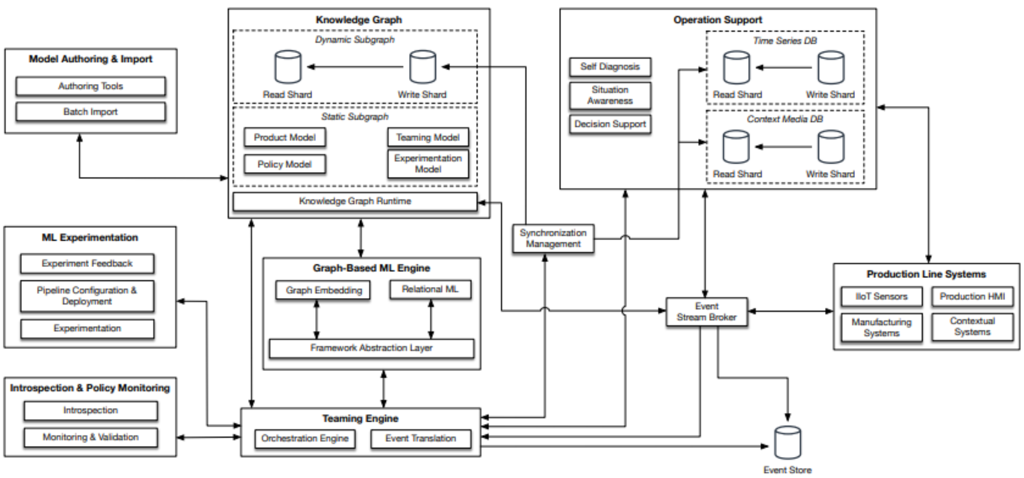
TEAMING.AI Software Architecture

With the proliferation of AI-enabled software systems in smart manufacturing, the role of such systems moves away from a reactive to a proactive role that provides context-specific support to manufacturing operators. In TEAMING.AI we focus on **knowledge graphs** (KG) to capture product and process specific knowledge in the manufacturing process and on **relational machine learning** to utilize the information in the KG for context specific recommendations for the optimization of product quality and the prevention of physical harm.

In multiple workshops over the course of six months, our research consortium identified two main challenges relevant for a reference software architecture for human-AI teaming in smart manufacturing. The first challenge relates to the required **scalability of the architecture** when processing data in near-realtime, particulary in combination with relational machine learning, i.e., the statistical analysis of graph-structured data. The second challenge relates to examining a suitable framework to **explicate the knowledge** for effective teaming in the manufacturing process. Shared mental models capture the common ground knowledge in the collaboration between humans and AI services. We use knowledge graphs and ontologies to formalize these shared mental models of the manufacturing process and the semantics of trust factors for human-AI teaming in an operational manner.

Based on these challenges, our research consortium developed a reference software architecture that serves as a blueprint for our subsequent research activities and validations. Though this architecture merges different viewpoints from researchers with software engineering and machine learning backgrounds, we expect subtle changes with further progress of the research project.



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Above figure shows the different components of this **reference software architecture**. To account for the different latency requirements of the components to process the data in a streaming-like manner, we followed the Lambda architecture pattern as described by Warren and Marz[1]. This architectural pattern groups the components based on their latency requirements into three layers. The **batch layer** (model authoring) ingests and stores large amounts of data, the **speed layer** (knowledge graph, graph-based ML and teaming engine, production line systems) processes updates to the data in low-latency, and the **serving layer** (operation support, ML experimentation, introspection & policy monitoring) provides precalculated results also in a low-latency fashion. To separate read and write operations and therewith be able to balance the processing of large data volumes, all data stores used in the architecture (i.e., dynamic knowledge graph, time series, and media data) are replicated as read and write shards. The synchronization between these replicas is performed autonomously by the synchronization management component. The empirical validation of this software architecture will be conducted in cooperation with three large-scale companies in the automotive, energy systems, and precision machining domain.

For an in-depth discussion about the identified challenges for such a reference software architecture, its preliminary status, and a sketch of our further research vision in this project please see our paper[2] that will be presented at the International Conference for Software Engineering (ICSE-2022, May 22-27).

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[1] James Warren and Nathan Marz. Big Data: Principles and best practices of scalable realtime data systems (1st edition). Manning (2015).

[2] Haindl, Philipp, et al. "Towards a Reference Software Architecture for Human-AI Teaming in Smart Manufacturing." arXiv preprint arXiv:2201.04876 (2022).