

1. Introduction

The integration of Large Language Models (LLMs) and Digital Twins technologies (virtual replicas of physical systems) opens up new possibilities for process analysts and engineers by (semi-)automating process discovery and (re)design within the Business Process Management (BPM) lifecycle. These critical steps form the foundation for developing any sustainable Process-Aware Information System (PAIS). Traditionally, these steps are tedious and prone to errors, but the advancements in Generative AI, particularly LLMs like those from OpenAI (ChatGPT), Llama, and Mistral, show potential. This is because LLMs have significantly become better in understanding the semantics and context present in large volumes of unstructured data such as documents, emails, maintenance logs, operational videos, and chat exchanges.

2. Problem Statement

Europe faces a major challenge in strengthening the resilience of its systems while managing the socio-economic impacts of digital transformation, especially in sectors such as manufacturing and healthcare:

- The growing skills gap between traditional expertise and digital proficiency highlights the need for leveraging emerging technologies
- The skill gap is widening as experienced workers retire or transition, making workforce upskilling and reskilling crucial to meet new demands

Instead of replacing workers, systems leveraging AI present a promising solution to bridge the skills gap by assisting in the comprehension and design of complex processes and systems:

- Supporting analysts in navigating emerging regulations such as AI Act, Chip Act
- Enhancing operational efficiency and sustainability by identifying opportunities to optimize energy and resource use during the (re)design or (re)analysis phases
- Enabling less experienced workers (or new hires) to grasp and operate complex processes without needing in-depth knowledge from the start

3. Research Questions

Q1. How can LLM-based agents be optimized by combining model fine-tuning with Retrieval-Augmented Generation (RAG) to deliver outputs that align with user requirements and real-world constraints in process-aware environments, such as manufacturing and healthcare?

Q2. How to address challenges related to data scarcity and privacy (e.g., GDPR) during the domain-specific data processing to enhance the quality and accuracy of the system, while supporting the stakeholders in making informed decisions?

4. Experimentation

This study explores the integration of LLMs to systems used to model and design Digital Twins (both Process and Product Digital Twins), which are integral to a Digital Product Passport (DPP). We developed custom Generative Pre-trained Transformers (GPTs) based on OpenAI's ChatGPT, focusing on refining prompts (prompt engineering) and incorporating internal knowledge from standards like BPMN, UML, SysML, and related documentation (see Fig. 1). Our approach underlines rapid prototyping, leveraging OpenAI's intuitive tools to integrate domain knowledge and enable Retrieval-Augmented Generation (RAG) for quick assimilation of updated reports (see Fig. 2). However, a key challenge lies in the black-box nature of internal knowledge management in these custom GPTs. This makes them impractical for handling proprietary data due to confidentiality constraints, thus restricting testing to open data and standards.

Despite these limitations, the custom GPTs have demonstrated promising results. Furthermore, this approach of leveraging OpenAI for initial prototyping has significantly reduced both GPU resource costs and development efforts. The insights gained from this approach will ultimately support the integration of Open LLMs with an RAG system in the FactoryIA initiative at CEA-List.

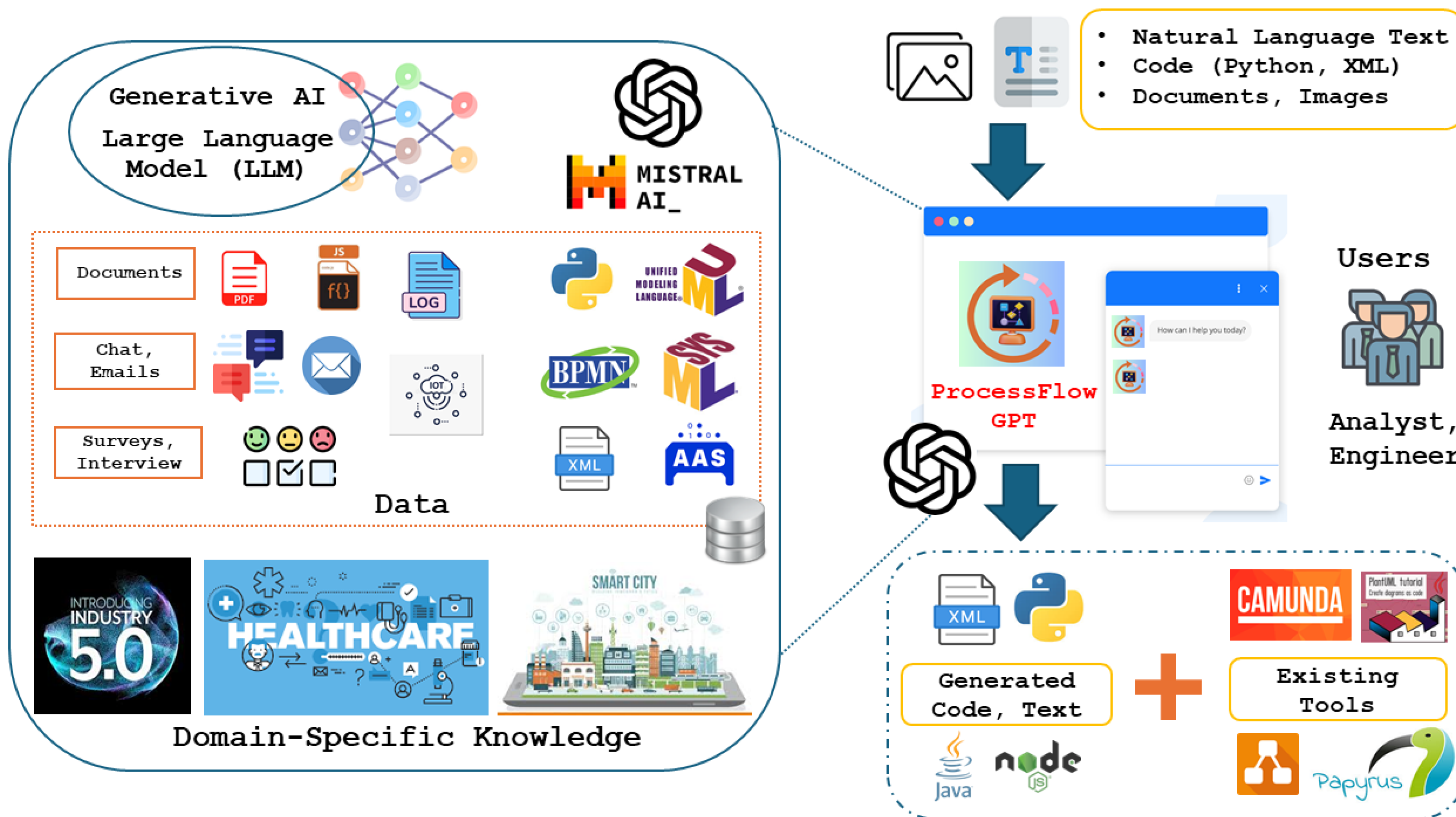


Fig. 1: Architecture illustrating components of a LLM-integrated System

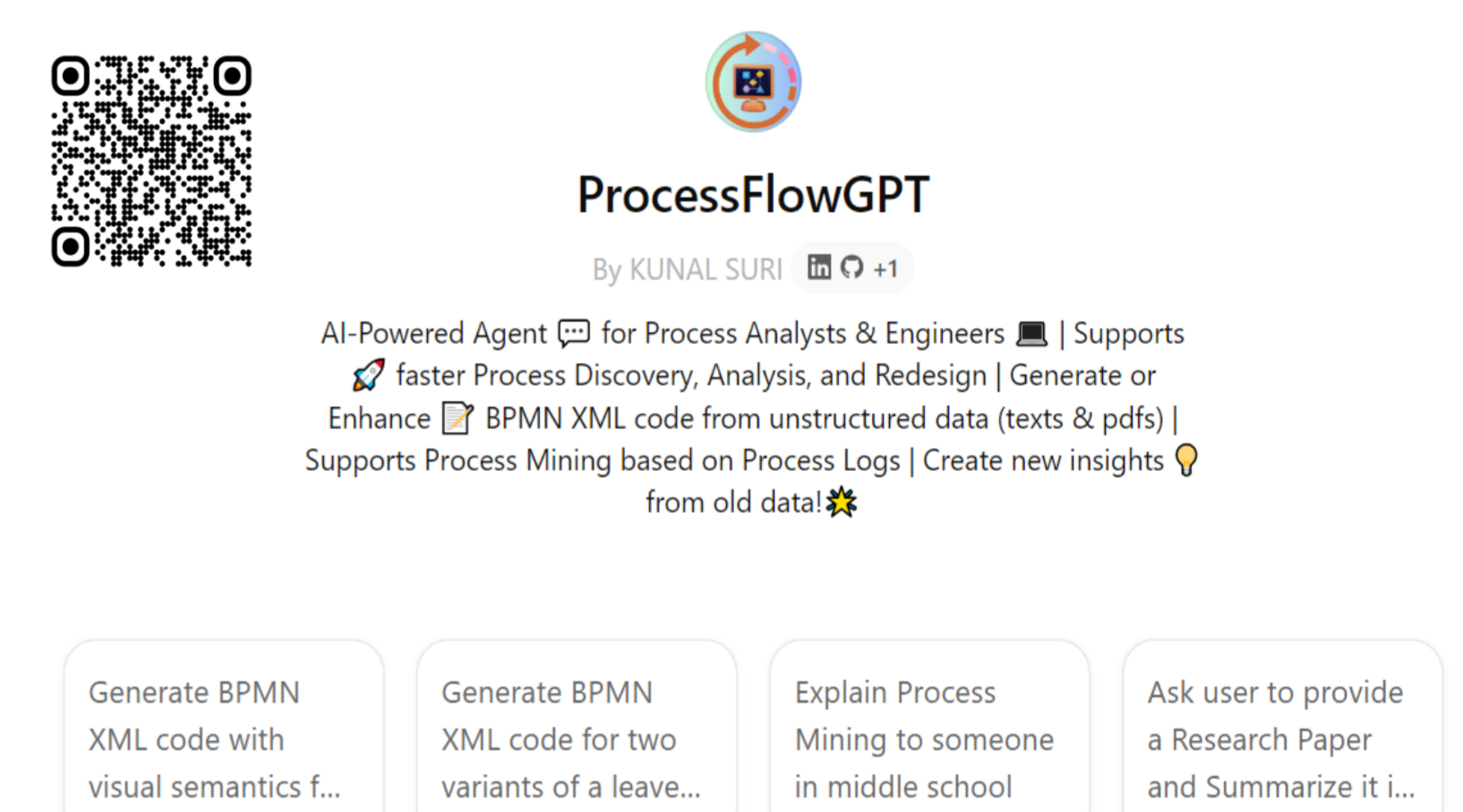


Fig. 2: Example of a Custom GPT

5. Conclusion & Future Works

- The integration of LLMs with systems used to develop Digital Twins (including Process and Product Digital Twins) will significantly enhance traditional modelling techniques, addressing key challenges in fast-evolving process-aware sectors such as manufacturing (Industry 5.0), healthcare, and smart cities.
- These systems offer (semi-)automated, domain-specific, data-driven optimizations by utilizing both structured and unstructured data. This aids decision-making, facilitates compliance with new regulations (e.g., GDPR, AI Act), and helps bridge Europe's widening skills gap, which is intensified by the retirement of experienced workers and the increasing demand for digital expertise.
- As this research advances, it will further explore the benefits and limitations of these AI agents, laying the technological foundation and offering practical insights for integrating LLMs with systems used to develop Digital Twins to support upskilling, resource optimization, and sustainable operations.