Large Language Models for maintenance engineering with applications to energy systems

Context of the research

Effective maintenance is critical to ensuring the availability, reliability, and safety of industrial systems. Traditionally, maintenance decision-making relies on expert analysis of technical reports, historical failure data, and maintenance logs. However, these textual documents are often unstructured, extensive, and vary in quality and terminology, making it difficult to extract and quantify key insights about system behavior, failure causes, and maintenance effectiveness.

Large Language Models (LLMs) are emerging for their capabilities of understanding natural language, extracting relevant information, and reasoning. This research explores the use of LLMs with the aim of supporting maintenance engineering decisions.

The specific objective is to use LLMs to automatically model the relationships among maintenance actions, observed events and failure causes by using: *i*) a formal ontology representing the domain-specific knowledge, *ii*) textual descriptions of the system and the maintenance procedures, and *iii*) repositories of maintenance reports. Then, a procedure for systematically querying the LLM will be developed to guide maintenance decisions.

The potential of the methodology will be explored through its application to energy systems—including power generation, renewable installations, and smart grids—oil and gas assets and nuclear facilities.

Objective of the research

This research aims to develop a methodology based on Large Language Models to support maintenance engineering decisions. The activity will include:

- Literature review on LLMs and their application to industrial maintenance;
- Definition of the research problem;
- Development of the methodology;
- Application to a practical case study;
- Validation;
- Writing of scientific papers, as chapters of the thesis.

Required competencies and skills

- Interest in developing innovative applications of Natural Language Processing, Machine Learning and Artificial Intelligence algorithms for maintenance engineering;
- Good knowledge of Python programming or willingness to learn.

Composition of the research group

- 2 full professors;
- 2 postdoctoral researchers.

Total thesis duration

- 6 to 8 months.

For further information, please contact:
Prof. Piero Baraldi, piero.baraldi@polimi.it
Prof. Enrico Zio, enrico.zio@polimi.it