LASAR^3
Laboratory of Analysis of Systems for the Assessment of Reliability, Risk and Resilience

Automatic Interpretation of Engineering Schemes for LLM-based Risk Assessment

Context of the research

Engineering schemes such as Piping and Instrumentation Diagrams (P&IDs), electrical schematics, and related technical diagrams are among the most important sources of knowledge for understanding the architecture, behavior, and operation of industrial systems. Engineers rely on these schemes to identify system components, reconstruct functional relationships, and understand how equipment, control elements, and protection mechanisms interact. This information is fundamental for conducting risk assessment studies such as Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis (FTA), and other safety and reliability analyses.

However, the interpretation of engineering schemes is still largely manual, time-consuming, and dependent on expert knowledge. While recent AI methods have shown promising capabilities in document understanding and information extraction, most existing approaches focus primarily on recognizing isolated symbols, text labels, or component lists. These approaches present two key limitations: 1) they often extract components without reconstructing the functional logic of the system, such as flows, control dependencies, and cause-effect relations; and 2) they do not support a reasoning process able to integrate visual, symbolic, and contextual information across the scheme in order to build a coherent system-level understanding.

The research proposed here aims to develop an AI agent-based method for the automatic interpretation of engineering schemes, capable of taking as input P&IDs, electrical schematics, and similar technical diagrams, and producing as output both the list of system components and a structured representation of the functional logic of the system. The idea is to combine diagram understanding techniques with LLM-based AI agents that can iteratively inspect the scheme, interpret symbols and textual annotations, infer relationships among components and reconstruct the operational and functional organization of the system.

The method will be evaluated on benchmark diagrams and on a realistic engineering case study.

Objective of the research

This research aims to develop an AI agent-based method for the automatic interpretation of engineering schemes. The activity will include:

- Literature review on methods for automatically analyzing system scheme (e.g., P&IDs, electrical schemes) with their application in safety engineering;
- Definition of the research problem;
- Development of the methodology;
- Application to benchmarks and realistic case studies;
- 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 Reliability, Availability, Maintainability and Safety of industrial system;
- Good knowledge of Python programming or willingness to learn.

Collaborations

Department of Electronics, Information and Bioengineering (DEIB)

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