Automated System Logic Representation by P&I Digitalization

In collaboration with TRACTABEL (ENGIE) - Bruxelles- Belgium

Context of the research

Preventing and mitigating failures is essential to guarantee the availability, productivity and safety of industrial systems. In the context of safety and risk engineering, system logic representation is a formal approach to modeling the functional and failure relationships within a system. Fault trees are an example of system logic representation and Fault Tree Analysis (FTA) is a widely adopted methodology for assessing system failures and their root causes, enabling engineers to identify potential risks and implement mitigation strategies. However, constructing fault trees remains a complex and time-consuming task, requiring extensive domain expertise, system information and data. In many cases, particularly for new and innovative systems, only limited information is available, such as process descriptions and piping and instrumentation (P&I) diagrams, whose interpretation is highly dependent on expert judgment, which introduces subjectivity in the fault tree construction process. Large Language Models (LLMs) have recently emerged as a powerful tool of artificial intelligence with remarkable capabilities in natural language understanding, knowledge extraction, and reasoning. The related possibility to process and synthesize information from diverse textual sources presents an opportunity to automate fault tree analysis, even in scenarios where only partial system descriptions and P&Is are available. This thesis work is aimed at developing a methodology based on LLMs to automate the generation of fault trees from P&I. The objective is to address challenges related to incomplete information and expert subjectivity. The methodology will be designed to interpret textual descriptions and P&Is, extract relevant failure relationships, and construct structured fault trees to support risk assessment. The effectiveness of the proposed approach will be demonstrated through case studies on industrial systems, evaluating the accuracy and reliability of LLM-generated fault trees compared to traditional expert-driven methods.

Objective of the research

This research aims to develop a methodology based on LLMs to automate the generation of fault trees from P&IDs. The activity will include:

- Literature review on LLMs and their application to risk assessment, particularly system logic representation, (e.g., fault tree analysis);
- Definition of the research problem;
- Development of the methodology;
- Application to a case study;
- Validation;
- Writing of scientific papers.

Collaborations

Tractebel, part of the Engie Group, is a leading engineering firm specializing in energy and nuclear safety. The work will be performed in the Laboratory of Analysis of Systems for the Assessment of Reliability, Risk and Resilience (LASAR^3) of Politecnico di Milano in tight collaboration with TRACTABEL in Bruxelles (Belgium), where an internship is foreseen.

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