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

Development of AI Agents and Large Language Models for Automated Fault Tree Analysis of Industrial Systems

Context of the research

Fault Tree Analysis (FTA) is one of the most widely adopted techniques for reliability and safety assessment of industrial systems. It enables a structured representation of the logical combinations of component failures that may lead to system failure. FTAs are extensively used in sectors such as energy, process industry, aerospace, and transportation to support risk-informed decision making and maintenance planning.

Despite their importance, the construction and updating of fault trees remain largely manual, time-consuming, and highly dependent on expert knowledge. Engineers must interpret heterogeneous information sources technical reports, maintenance logs, failure databases, operating procedures, system schematics and translate them into formal logical models. This process is prone to subjectivity, inconsistencies and limited scalability.

Recent advances in Large Language Models (LLMs) and Artificial Intelligence (AI) agent frameworks offer new opportunities to support and automate FTA development. LLMs combined with Retrieval-Augmented Generation (RAG) can extract relevant failure knowledge from domain and system-specific source of information, while AI agents equipped with reasoning and coding tools can translate this knowledge into formal fault tree structures, perform quantitative analyses and interact with human experts. Such systems could significantly reduce modelling effort while improving traceability and consistency with the domain and system specific knowledge.

The research proposed here aims to design an intelligent multi-agent framework that integrates LLM reasoning, information retrieval, and reliability analysis tools to assist engineers in building, validating, and updating fault trees for industrial applications.

The methodology will be tested on benchmark datasets and on realistic case studies of complex and energy systems.

Objective of the research

The objective of this research is to develop and demonstrate an AI-based methodology for the automatic generation and analysis of fault trees using LLMs and AI agents. The activity will include:

- Literature review on FTA, knowledge-based safety modelling, and applications of LLMs in reliability 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 complex system;
- Good knowledge of Python programming or willingness to learn.

Composition of the research group

- 2 full professors;
- 1 postdoctoral researchers;

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