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

Advanced Retrieval Augmented Generation for LLM-based Risk Assessment

Context of the research

Large Language Models (LLMs) are increasingly adopted in engineering applications to support knowledge-intensive tasks such as design, diagnostics, maintenance and risk assessment. When combined with Retrieval Augmented Generation (RAG), these systems can ground their responses in external knowledge sources, improving factual accuracy and domain relevance. However, standard RAG approaches are typically based on vector similarity search over unstructured text chunks and present two key limitations: 1) retrieved information often lacks sufficient organization and contextualization to capture system-level relationships, dependencies, and causal mechanisms; 2) retrieval is driven by static queries, which are not adapted based on intermediate reasoning steps. These limitations become particularly critical in industrial applications, where knowledge is heterogeneous, diverse and distributed across multiple sources, including technical documentation, accident databases, engineering models and expert insights. As a result, identifying the most relevant information for complex and interconnected systems remains difficult, especially in safety-critical and high-risk engineering contexts.

The research proposed here aims to develop advanced RAG methods for integrating expert and system knowledge into LLM-based AI agents. The idea is to combine heterogeneous engineering knowledge sources with retrieval strategies that can adapt to the problem being solved, iteratively refine the search process and identify the most relevant information for intermediate reasoning steps. In this setting, the AI agent uses retrieval as a tool to select appropriate sources, reformulate queries, gather complementary evidence and construct the contextual information needed to support downstream reasoning. The retrieved information is then used to augment the prompts of LLM-based methods and AI agents, enabling more accurate, interpretable and context-aware reasoning in risk assessment applications of industrial systems.

The method will then be integrated with an already developed LLM-based risk assessment method and evaluated on benchmark tasks and on a realistic engineering case study.

Objective of the research

This research aims to develop a method for integrating expert and system knowledge into LLM-based AI agents through advanced RAG methods. The activity will include:

- Literature review on RAG 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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