Large Language Models for Systems Engineering

Cyber-physical systems (CPS) are complex, interconnected systems comprising various software and hardware components. Their complexity is constantly growing, compounding the challenges engineers face. We envision leveraging large language models (LLMs) and generative AI to improve processes, manage and share knowledge, orchestrate the use of large toolkits, and provide human-centric assistants.

Processes improvement

Since numerous systems engineering challenges can be effectively addressed by analyzing and generating data, text and code, we envision LLMs as a powerful add-on to improve processes. Since LLMs' emergence, much effort has been put into using them to generate code and provide code improvement suggestions (e.g., GitHub Copilot). ESI envisions that LLMs can be applied in the entire system engineering process to support various system design and diagnosis tasks, such as design suggestion generation, design compliance checking, bug triaging and localization, and predictive maintenance. LLMs can also assist Model-Based Engineering (MBE) in creating, transforming and maintaining models that capture various aspects of systems. These tasks can be non-trivial, requiring system knowledge and expertise in modeling/domain-specific languages and tooling. We envision LLMs suggesting model transformations and guiding engineers in refining the system modeling.

Knowledge management

Engineering CPSs typically requires collaboration among experts from diverse disciplines, including electrical engineering, computer science, mechanical engineering, etc. Experts must navigate through various layers of abstraction, from the application layer down to the hardware layer, to comprehend the system architecture thoroughly and perform their engineering tasks. However, coordinating efforts among team members with different expertise and perspectives is difficult and requires multi-domain knowledge along with effective communication skills.

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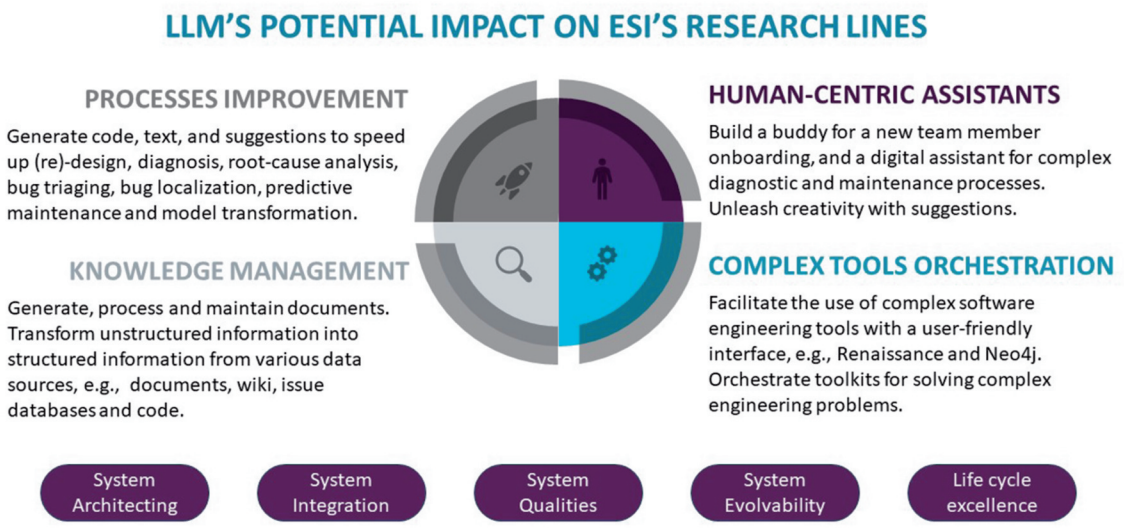

To ease knowledge management and sharing, we envision that LLMs can help with:

- Generating, processing and maintaining documents. LLMs have shown the ability to generate documents to describe code fragments; we believe they can be further leveraged to generate documents for system design and architecture by using data from various information sources (e.g., slides, UML diagrams, and outdated documents). The ability to translate engineering artifacts into human-readable texts can also ease knowledge sharing among engineers with different levels of seniority and different roles and domain background. Furthermore, large language models may be leveraged to find inconsistencies among engineering artifacts (e.g., code and design documents).
- Transforming unstructured information into structured information to enable the use of analysis tools. For example, one challenging and time-consuming activity engineers often perform when working on a new/complex codebase is to comprehend the system with some abstraction by drawing architecture diagrams. LLMs can support gathering information to generate architecture diagrams from documents or codebases, helping engineers get insights into the system architecture.

Complex tools orchestration

There are many toolkits available for system engineers to perform a variety of engineering tasks. Two challenges are significant when it comes to using these toolkits. Firstly, these tools often have a steep learning curve due to the complex nature of the problem domains. Secondly, solving an engineering problem usually requires engineers to use several tools. For example, a root cause analysis activity may require engineers to gather useful information from static code analysis, log analysis and performance profiling tools, and then determine the root cause based on the outputs provided by these tools.

LLMs can potentially address these challenges in two ways:

- Providing a chat-like interface to ease the use of these tools. An engineer can ask questions in natural language which are translated by LLMs into formal and executable queries for these tools. For example, to help engineers understand the dependencies between code entities, LLMs can translate their questions into queries that can search through a code graph and provide answers based on the dependency information.
- Orchestrating the large toolkits. Imagine that given a certain engineering problem, an agent-based LLM can logically and strategically execute tools, gather useful information from them, and analyze this to assist engineers. The orchestration ability of LLMs will reduce the time developers spend reasoning and switching between different tools.

Human-centric assistants

LLMs, as a revolutionary technology, will also help us meet the vision of industry 5.0 where engineering solutions should be human-centric, keeping engineers in the loop. We aim to leverage LLMs as digital assistants in the engineering process. By providing a chatbot-like interface, LLMs can interact with engineers and serve as a buddy. Imagine that you are a newcomer to a company, LLMs can get you onboard by answering your company-specific and system-specific questions. If you are a system architect facing a system failure in the field, LLMs can guide you to perform root-cause analysis, suggest corrective action, and generate accurate reports about the incident. LLM-based digital assistants can empower engineers to more efficiently solve engineering problems.

How will you apply large language models to the engineering challenges your company is facing?