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A COMPUTATION ENGINE FOR NUMERICAL SYSTEM REQUIREMENTS GENERATION IN LLM-BASED SPACECRAFT DESIGN ASSISTANTS

Abstract

The design of spacecraft, and more broadly of space missions, can greatly benefit from LLM-based design assistants supporting engineers in the extraction of relevant information from past missions for its reuse in the new one, as well as in the automatic generation of system requirements in text at different levels. However, due to the mathematical nature of technical systems, many of the spacecraft requirements are numerical and involve calculations or the application of first principles. And while Large Language Models excel at text generation, predicting the next words in a sequence with the highest probability, they are not suited, being statistical engines, to perform deterministic computations.

In this paper, we present the architecture of a computation engine to which numerical calculations are outsourced during the process of generating requirements by an LLM-based design assistant. We present the integration with the LLM, measure its performance, and benchmark and discuss the improvement in requirements generation with existing space missions as use cases.

In particular, the computation engine hereby developed follows an object-oriented programming paradigm, mimicking through the classes the subsystems of a spacecraft, through the class properties their parameters, and through the class functions the equations and first principles used to calculate the parameters' values, which can be then expressed by the LLM as numerical system requirements with natural language. A high-level programming language and a modular approach are followed in seek of high readability and modifiability, allowing the engine to be extended and its granularity increased in future iterations. Different alternatives for the integration of the computation engine with the LLM and in the design flow are evaluated and compared, and parameters such as the computation speed and error are measured and assessed along different computation platforms.

By presenting this computation engine for spacecraft design, we aim at patching the shortcomings of LLM-based design assistants in numerical calculations, paving the way for their adoption, and thus helping accelerate and simplify spacecraft design for a broader range of institutions and individuals.