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A DIGITAL EXPERT FOR SPACE SUSTAINABILITY SIMULATIONS

Abstract

Commercial satellite launch traffic has rapidly increased in recent years following the advent of satellite mega-constellations, and the growing population of active satellites necessitates putting measures into place to mitigate the risks of debris creation and to ensure that the space environment remains safe for long-term use. While major space organisations have independently implemented policies for long term space sustainability, if commercial interests in space continue at the current rate, developing governmental policies on how private companies should approach satellite management may be necessary.

The impacts of different approaches for debris mitigation can be modelled via simulation, establishing the effects of different policy-led restrictions. While such simulations can provide useful forecasts of how the space environment would be affected under different circumstances, and allow for a suitable balance to be determined that preserves the usability of orbital space without unduly curtailing either scientific or commercial interests, interpreting their outputs often requires specialist knowledge. This can pose difficulties for policy makers seeking to investigate the outcomes of a possible set of policies, as it may be impossible to independently interact with the tools needed to evaluate them. To make these forecasts more accessible for policy makers, we propose the use of language model (LLM)-based “digital expert”, and provide an example for the NEtwork model for Space SustainabilitY (NESSY) simulation.

NESSY models interactions between satellites and debris as dictated by a number of user-selected policies (including active debris removal rate, mission lifespan and success of post-mission disposal) and returns a series of numerical “health indicators” which are mathematically grounded but require expertise to interpret. We use the Llama family of LLMs for our digital expert to provide these interpretations for users via a chat platform. As this requires specific technical knowledge which the “base” Llama models do not have, we make use of retrieve augmented generation (RAG), a technique which allows our model to draw information from a curated knowledge bank of documentation when answering questions. This approach allows us to leverage the flexibility of an LLM to provide explanations of simulation results tailored to the user’s expertise level while requiring that all responses are supported by factual information, preventing LLM hallucinations. We are presently developing similar digital experts for other forecasting models, with the aim of providing integrated tools that aid policy makers in making informed assessments of policy outcomes for the future of the space environment.