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LLM-assisted initial problem conceptualization in decision-making under deep uncertainty

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Abstract: Managing complex systems and future planning almost always involves deep uncertainty that cannot be eliminated until the future unfolds. To develop plans that remain robust and adaptive across unpredictable futures, researchers have proposed Decision-Making under Deep Uncertainty (DMDU) approaches. These approaches generally consist of three iterative steps: (1) problem conceptualization, (2) exploratory analysis, and (3) plan deployment. Specifically, model components are first identified, and the decision-making problem is formalized; then, alternative policies are explored across various plausible conditions; and finally, an initial plan is implemented and adapted as the future unfolds.

The effective implementation of these approaches requires collaboration between two groups: stakeholders and modellers. Stakeholders are those affected by the decisions and may represent diverse institutions with heterogeneous interests. Modellers specialize in formalizing problems as models that inform and guide decision-making. Nevertheless, differences in perceptions, worldviews and interests often lead to communication gaps between different stakeholders and between stakeholders and modellers, especially in the problem conceptualization process. Although previous studies have proposed tools to bridge these gaps, their effective use still relies on substantial human effort.

Instead, this paper aims to bridge these gaps using Large Language Models (LLMs). LLMs are machine learning techniques trained to process and predict human language. These techniques have also demonstrated the ability to extract and refine models from natural-language descriptions in other decision-making areas. To achieve our aim, we proposed a templated, LLM–assisted workflow to help stakeholders perform initial problem conceptualization. During this workflow, stakeholders begin with their intuitive problem description. On its basis, LLMs guide them to identify the essential model components, explore alternative perspectives approaching the problem, and eventually implement an initial Python model accordingly through iterative communication. These results are used to facilitate their communication with other stakeholders and modellers in subsequent steps.

We tested this workflow using ChatGPT-5 on two case studies in the experiments, the lake problem and the electricity market problem. The former is a benchmark problem related to social ecology, which has a standard implementation publicly available. The latter is a stylized socio-technical problem, which has been implemented differently in previous studies. The results indicated that, when following our workflow, ChatGPT-5 was able to identify model components and alternative perspectives consistent with the initial problem description and implement them in a Python program that was both syntactically and logically correct after only a few iterations with human verification and correction. Our experiments on other common LLMs also yielded similar results, although their performance was slightly worse than ChatGPT-5. In conclusion, our experiments demonstrated a viable avenue for leveraging widely available LLMs to support initial problem conceptualization in DMDU, and to explore alternative factors that may be overlooked given stakeholders' worldviews, so that the communication among stakeholders and modellers can be facilitated.

Keywords: *Decision-making under deep uncertainty, large language model, problem conceptualization, knowledge exchange*

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