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Can AI Function as a Virtual Combustion Researcher?

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Combustion is ubiquitous in systems as diverse as gas turbines [1], rotating detonation engines [2], and scramjets, yet its complexity continues to challenge both experiment and simulation. Over recent decades, high fidelity numerical solvers [3]—either for the full Navier–Stokes equations or reduced order models—have provided critical insight into combustion phenomena observed in the laboratory. However, setting up such simulations requires tens to hundreds of human-hours per study for tasks such as defining geometry, boundary conditions, mesh resolution, solver parameters, and post-processing routines for large, high-dimensional datasets [4]. In this work, we present a natural-language–driven workflow that leverages transformer-based language models [5] to automate end-to-end numerical combustion investigations. Given a simple researcher prompt, the system (1) generates a high-level experimental plan grounded in domain knowledge; (2) translates that plan into simulation scripts, domain setup, and solver configurations; (3) orchestrates distributed solver runs while monitoring for and recovering from runtime errors; and (4) extracts, analyzes, and summarizes key results into concise scientific insights. We test the framework on canonical numerical combustion benchmarks showing that AI-generated setups reproduce manually configured results within established tolerances, while reducing total setup-to-analysis turnaround. By integrating chain-of-thought reasoning [6] with automated task orchestration, the current approach preserves physical fidelity, accelerates parametric sweeps, and empowers researchers to explore novel hypotheses with minimal coding overhead. This work represents a step toward truly AI-assisted discovery in reacting-flow science, democratizing access to high-performance combustion modeling and fostering human creativity.

References

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