AQNSA: AGENTIC QUANTUM NETWORK SIMULATOR ARENA

A framework for replicating quantum network research with AI agents

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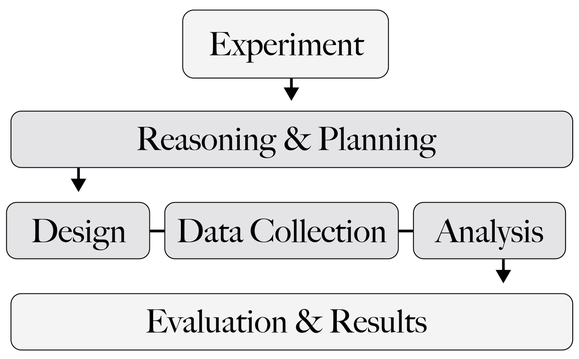
ABSTRACT

Advances in artificial intelligence (AI), particularly large language models (LLMs), have demonstrated effectiveness in technical tasks such as software engineering and code generation. However, their direct application to scientific experiments remain challenging, specifically quantum networks, where strict formalism and complex reasoning is demanded. We introduce the Agentic Quantum Network Simulator Arena (AQNSA), a framework designed to replicate and extend quantum networking research using AI agents. Given an experimental prompt, AQNSA orchestrates a multi-agent workflow in which a research agent develops a structured experiment plan and an engineering agent translates that plan into executable simulations using the Simulator of QUantum Network Communication (SeQUeNCe) framework. To ground agent reasoning and support planning and execution, we construct a knowledge graph from the cited materials of eight quantum networking studies selected for replication. Domain-expert graders evaluate agent reasoning traces, simulations and results. Our results investigate the feasibility of agentic research workflows for scientific experiments in quantum networks.

MOTIVATION

LLMs capabilities are advancing, reaching human-level performance in technical domains, notably in key research tasks such as coding and reasoning [1].



AI agents can perform multi-step tasks, allowing integration in scientific workflows [2], [3]. We examine their performance on quantum network research experiments.

METHODS

Dataset & Knowledge Graph

→ 8 quantum network publications selected as replication targets.

→ Knowledge graph constructed from all cited materials within each paper.

AI-Agent Framework

→ MCP and A2A protocols for multi-agent orchestration and tool use.

→ Arena platform designed to support full experiment lifecycle observability.

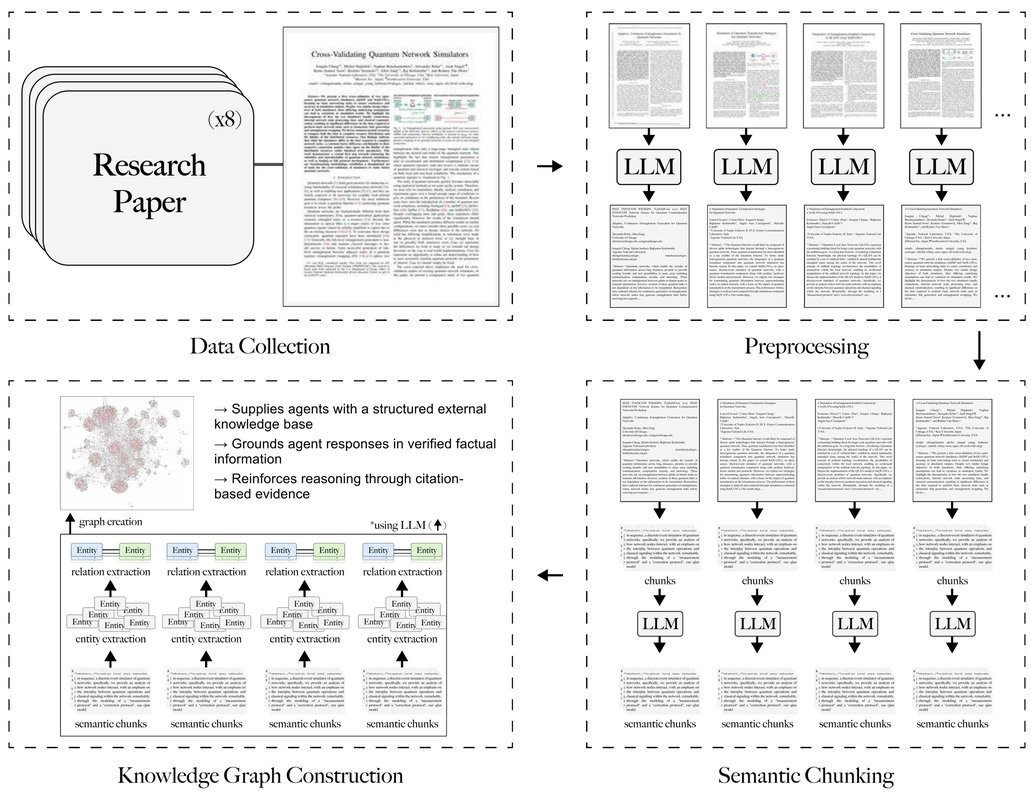
Experimental Arena

→ Arena used to execute and monitor full experiment lifecycles.

→ Benchmark established for autonomous research replication from our selected publication dataset.

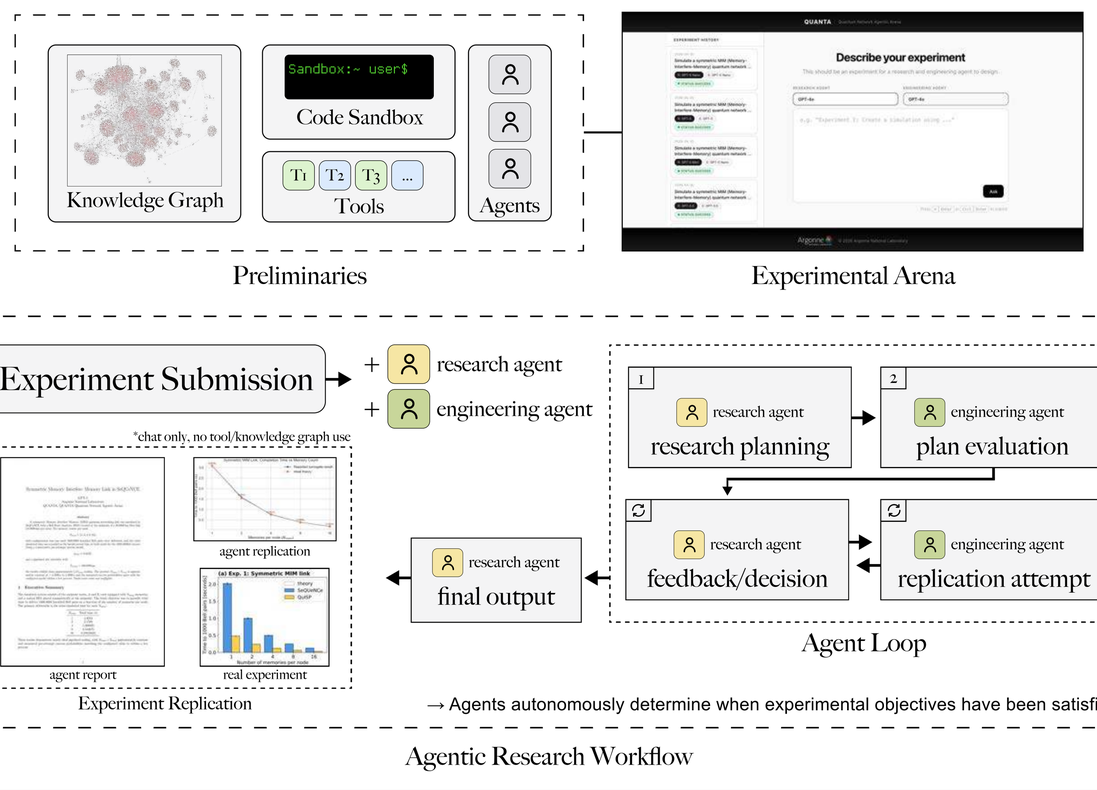
KNOWLEDGE GRAPH

Knowledge graph constructed from citations in 8 quantum network papers:



AGENT RESEARCH WORKFLOW

Agent workflow initiates with an experiment submission designated for replication:



CONCLUSIONS

1. Multi-step agentic workflows using research- and engineering-focused agents yield results comparable to existing experiments.
2. Chat-only agents with knowledge cutoffs predating publication demonstrate promising domain understanding in quantum networks.
3. Current proof-of-concept is limited by arena components still under development with evaluation over the full 8-paper benchmark dataset needed for rigorous findings.

NEXT STEPS

1. Complete remaining arena components to finalize a fully functional end-to-end replication platform.
2. Evaluate the agentic workflow across the full 8-paper benchmark dataset to assess AI-driven replication feasibility for quantum network research.
3. Refine the knowledge graph algorithm for higher-fidelity graph construction and strengthen the research workflow with agent graders, specialized agents, and expanded external tooling.

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