Qeios

Peer Review

Review of: "A Review of Formal Methods in Quantum Circuit Verification"

Zheng Shan[1]

1. Independent researcher

Summary & General Assessment

The manuscript provides a broad overview of formal methods applied to quantum circuit verification, covering barrier certificates, abstract interpretation, and model checking. While the topic is undeniably timely and relevant given the growing complexity of quantum programs, I cannot recommend this manuscript for publication in its current form.

To be frank, the paper feels like a **rough draft** rather than a polished submission. It suffers from severe presentation issues, a lack of depth in comparative analysis, and bibliographic errors that undermine its value as a survey. Below, I outline the critical reasons for this decision.

1. Critical Presentation and Readiness Issues

There are several indicators that the manuscript was not thoroughly proofread before submission, which raises serious concerns about the work's rigor:

The "Reviewer" Slip-up: In Section 8 (Future Directions), the text reads: *"as identified by the reviewer."* It is extremely confusing for the authors to refer to themselves as "the reviewer." This suggests that the text might have been copied from a previous peer review report or generated by an AI tool without proper editing. This anomaly alone casts doubt on the integrity of the writing process.

Bibliographic Sloppiness: A survey paper must provide a reliable index of the field. However, the bibliography contains duplicates (e.g., the paper "Efficient Formal Verification of Quantum Error Correcting Programs" appears multiple times) and metadata errors.

2. Lack of Depth and Synthesis

Beyond the formatting, the technical content is more of a "list of summaries" than a true synthesis.

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Missing Comparative Framework: The paper lists various methods (Model Checking, Theorem Proving, etc.) but fails to compare them systematically. Readers need to know: Which method handles noise better? Which is more scalable? What are the tradeoffs between automation and expressiveness? A survey should answer these questions, perhaps via a summary table, which is currently missing.

Superficial Treatment of Barrier Certificates: While the inclusion of barrier certificates is a highlight, the explanation is disjointed. The paper defines them mathematically but doesn't clearly explain the modeling bridge: how exactly do we map a discrete quantum circuit (with gates and measurements) to the continuous state-space constraints required by barrier certificates? The current description is too abstract to be useful for a practitioner.

3. Specific Technical Concerns

Abstract Interpretation: The section focuses heavily on robustness in VQC (Variational Quantum Circuits) but is titled generally. It misses the broader discussion on abstract domains suitable for general quantum program analysis (e.g., entanglement constraints).

Noise Modeling: The background section lacks a proper introduction to density matrices or CPTP maps, which are essential for understanding the verification of open quantum systems discussed later in the paper.

Conclusion

While I appreciate the effort to collate these references, the manuscript is premature. The combination of editing artifacts and lack of deep synthesis indicates that a major overhaul is needed.

I encourage the authors to take a step back, fix the fundamental definitions and formatting, clean up the bibliography, and—most importantly—develop a stronger comparative narrative. The paper should be rewritten and resubmitted as a new manuscript once these issues are resolved.

Declarations

Potential competing interests: No potential competing interests to declare.