VACSEN: A Visualization Approach for Noise Awareness in Quantum Computing

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- Background
- Motivation
- Approach
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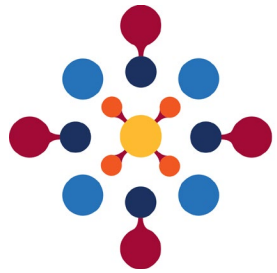
- Conclusion



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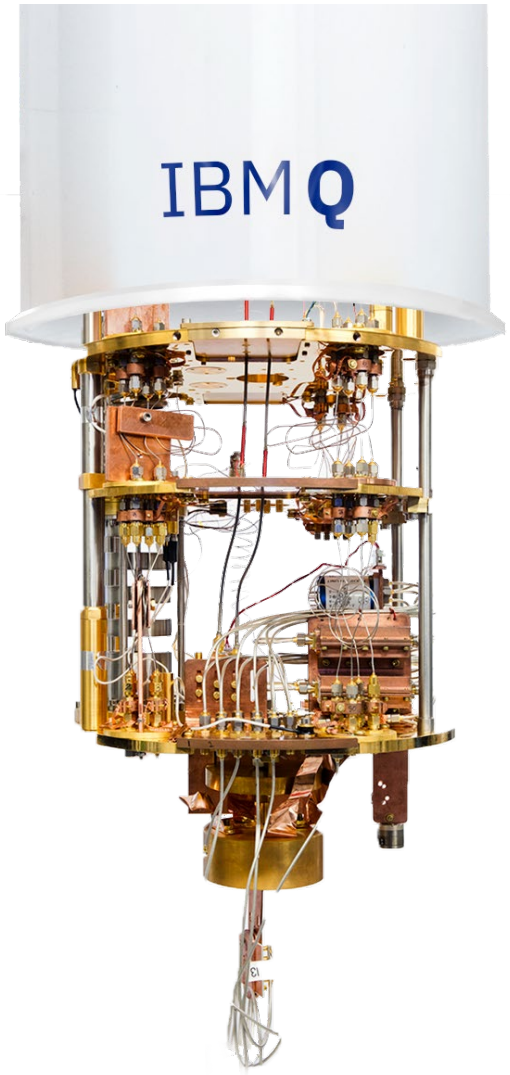


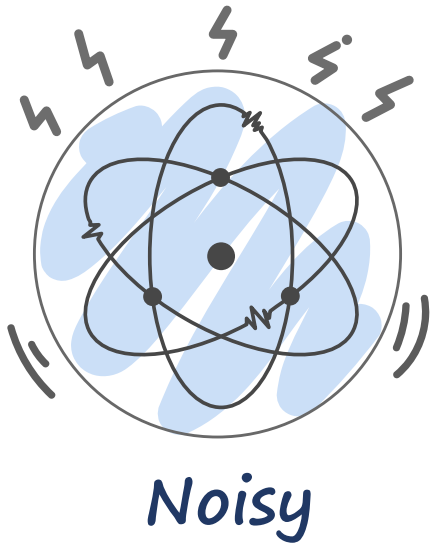
Quantum computers have shown a considerable speedup over classical computers [1]

[1] Arute F, Arya K, Babbush R, et al. Quantum supremacy using a programmable superconducting processor[J]. Nature, 2019, 574(7779): 505-510.

Background

Noisy Intermediate-Scale Quantum

- **The noise issues are severe and inevitable in today's quantum computers** [2,3]



[2] Bharti K, Cervera-Lierta A, Kyaw T H, et al. Noisy intermediate-scale quantum (NISQ) algorithms[J]. arXiv preprint arXiv:2101.08448, 2021.
[3] Preskill J. Quantum computing in the NISQ era and beyond[J]. Quantum, 2018, 2: 79.

Motivation

Noise in quantum computing

- **Noise from fundamental components in a quantum computer**
  - Qubits
  - Quantum gates

- **Noise from various compiled circuits**
  - Not deterministic topology
  - A large number of compiled circuits

Motivation

Noisy quantum circuit execution

- **No tool** to reflect the hidden noise
- The common practice to obtain less-noisy execution results is still a **trial-and-error** process with **a long queuing time** of up to hours.

Approach

Design Requirements

- **Quantum computer selection**
  - Facilitate the temporal analysis of various noise.
  - Make users aware of the latest noise.

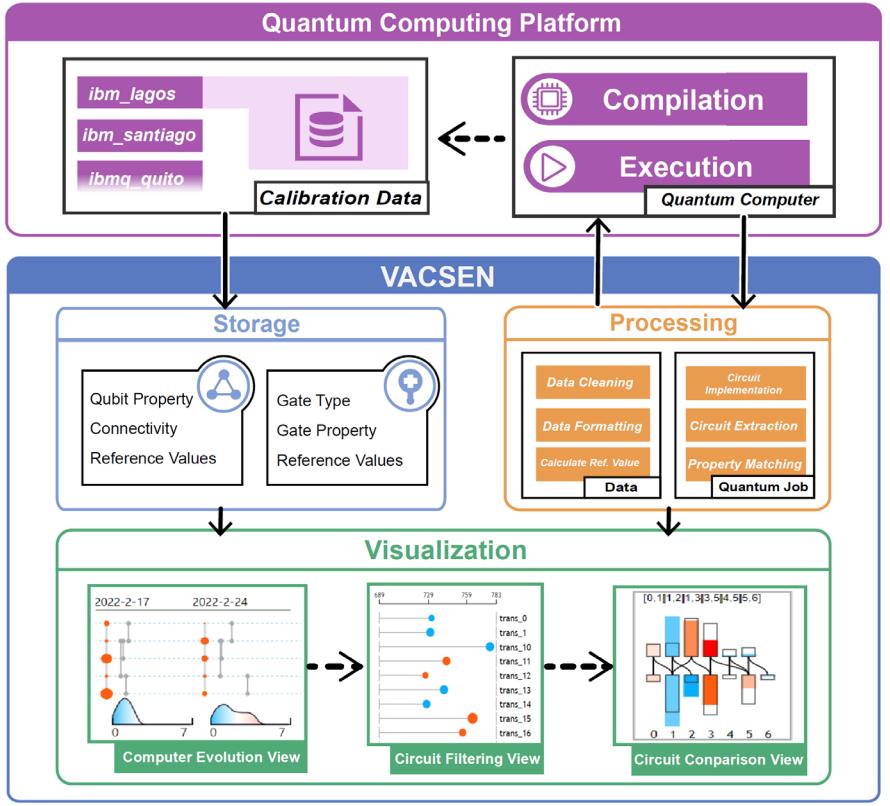
- **Compiled circuit selection**
  - Provide an overview of all compiled circuits.
  - Enable a detailed comparison of the usages of qubits and gates.
  - Support a real-time compilation and fidelity validation.

- **User Interaction**
  - Provide flexible user interactions and intuitive visual designs

Approach

Visualization system

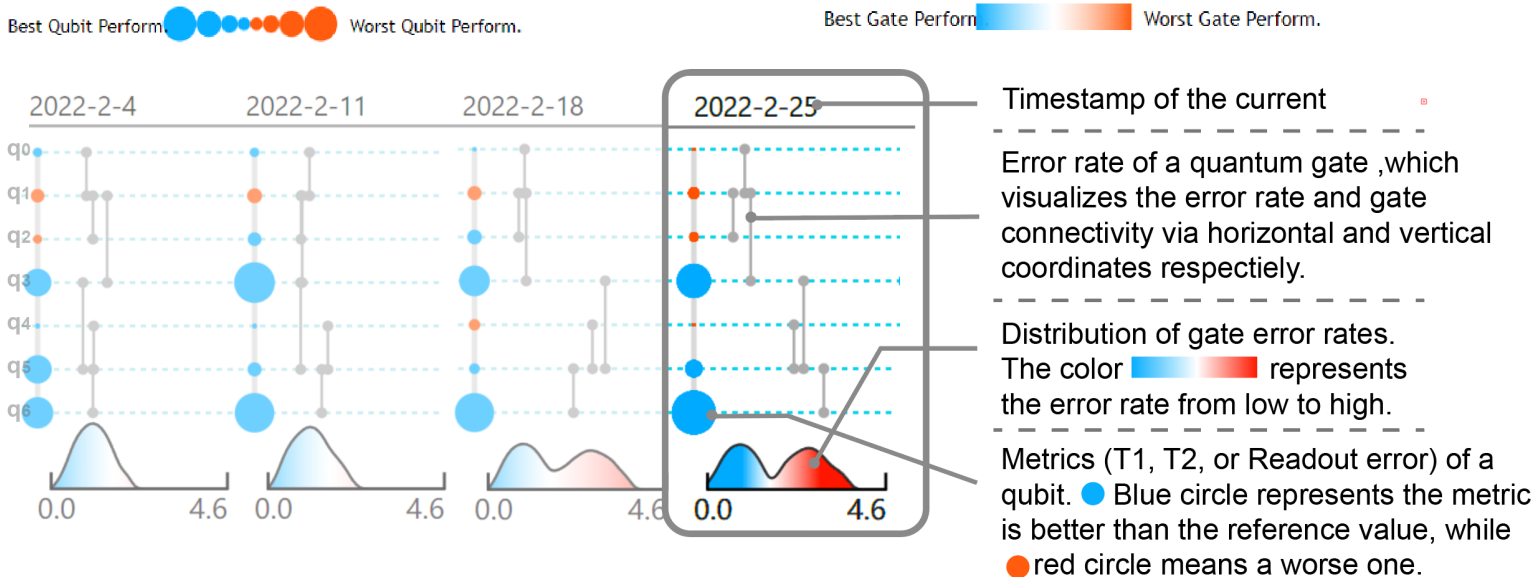
- VACSEN consists three modules: storage module, processing module, and visualization module. The system is connected to an external cloud quantum computing platform.



Approach

Circuit-like design

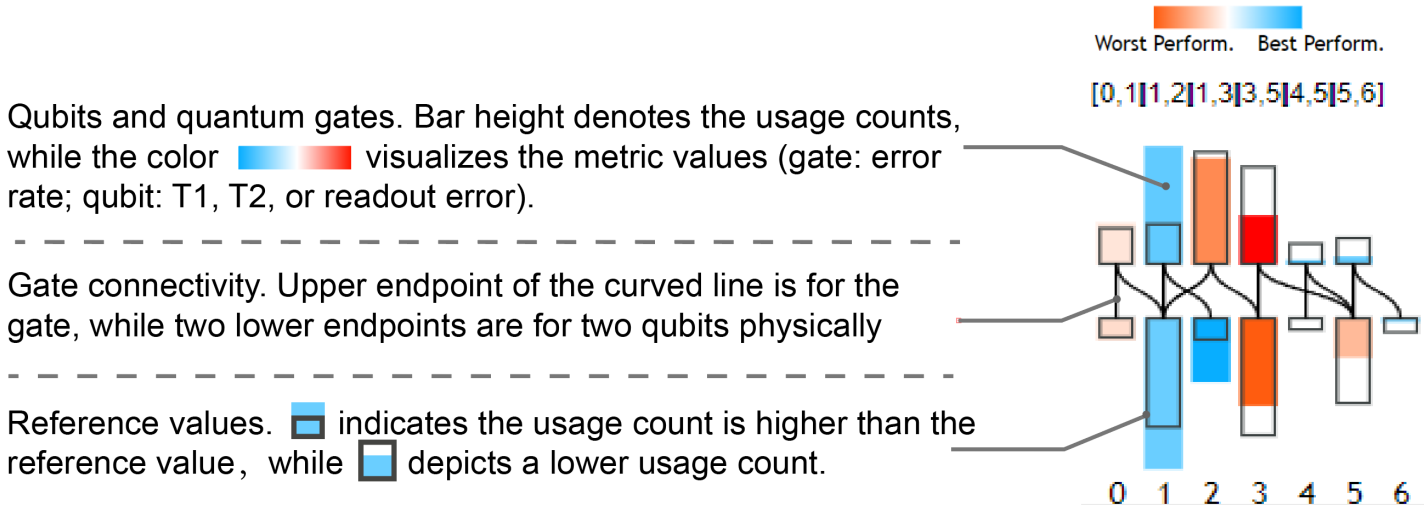
- **Challenge**: It is challenging to temporally visualize the complex noise factors as well as the qubit topological connections along a timeline.
- We propose a **circuit-like design** to portray the quantum computer noise in each time stamp.



Approach

Coupled bar chart design

- **Challenge**: It is difficult to visually summarize a large number of the compiled circuits regarding the various noises and enable users to select the most appropriate one shortly.
- We proposed **coupled bar chart** to support the in-depth comparison of multiple compiled circuits.



Evaluation

Case study

- **Quantum circuits:**
  - Two-qubit circuit
  - Shor's algorithm

- **Participants:**
  - Two domain experts from universities

- **Tasks:**
  - Perform quantum circuit execution with noise awareness provided by VACSEN

Evaluation

User interview

- **Participants:**
  - 12 domain experts
- **Tasks:**

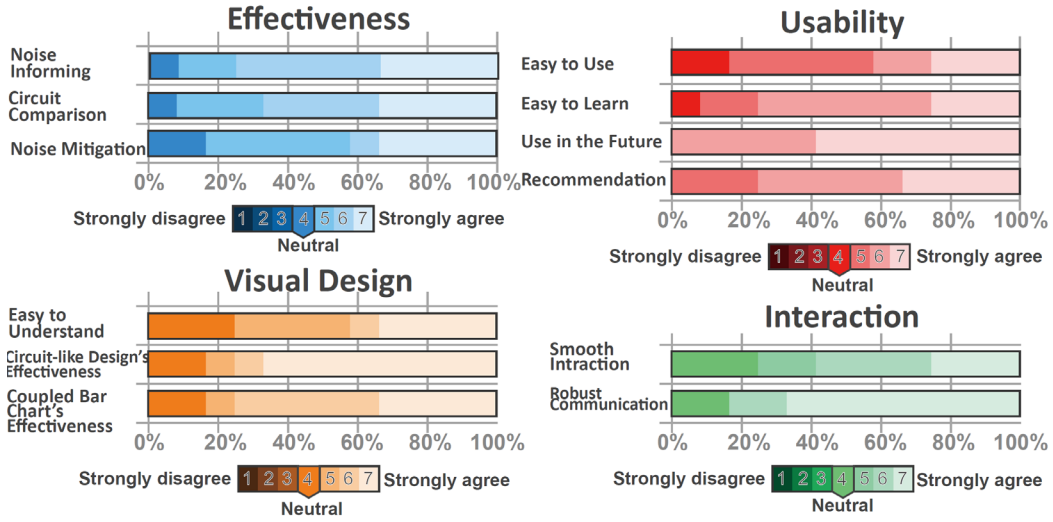
T1	Find the best-quality quantum computer regarding qubit's relaxation time *T1*.
T2	Find the best-quality quantum computer regarding qubits' dephasing time *T2*.
T3	Find the best-quality quantum computer regarding qubits' readout error.
T4	Find the best-quality quantum computer regarding gates' error rate.
T5	According to the tasks above, find the most suitable computer for the further execution.
T6	Find the circuits of interest regarding the quality of building blocks.
T7	Find the circuits of interest regarding the circuit depth.
T8	Compare and highlight the compiled circuits with good gate-quality for the final execution.
T9	Compare and highlight the compiled circuits with good qubit-quality for the final execution.

- **Methods**
  - Rating for VACSEN
  - Feedback

Evaluation

Results for the user interview

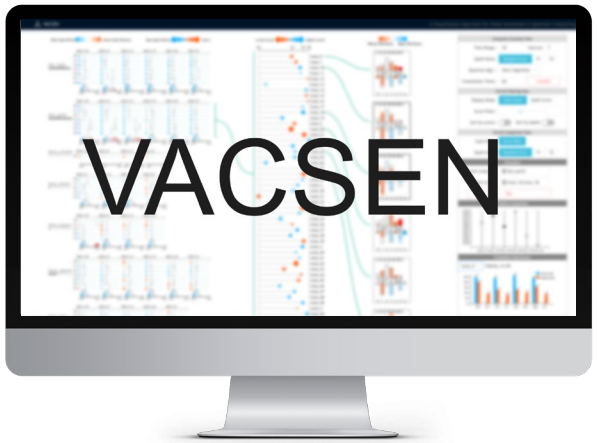
- **Likert-scale rating:**



- **Feedback:**

"I believe VACSEN will be helpful for our current research topic of quantum network routing. We can utilize VACSEN to host our different routing algorithm and get more accurate results as it can reflect various noises in real-time."

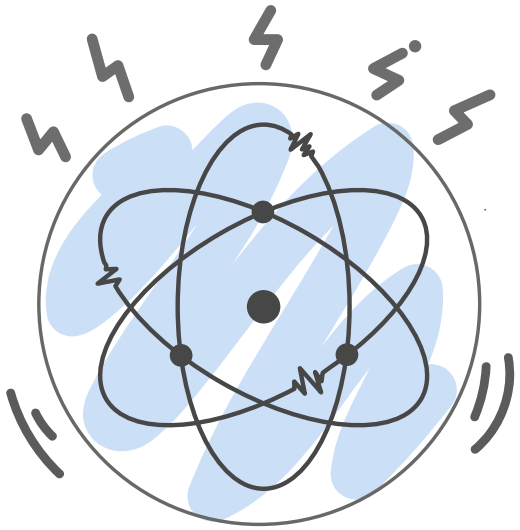
Conclusion



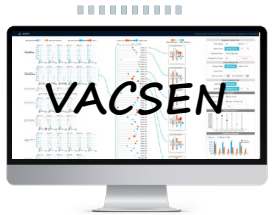
Conclusion

VACSEN supports a real-time **noise awareness** of quantum computers and compiled circuits, leading to a better circuit execution with **higher fidelity**

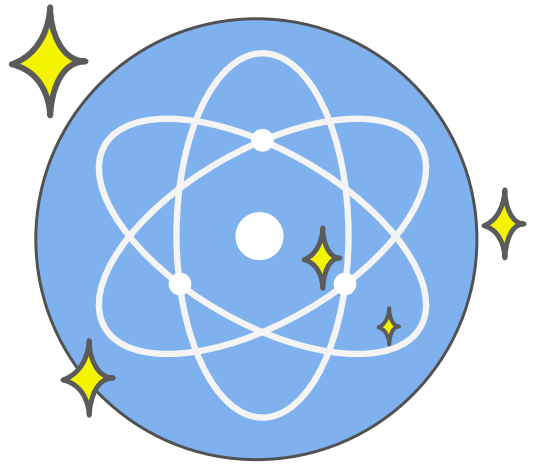
Conclusion



Noisy



Inform users of the quantum noise



Reliable

Thank you for your attention!

Q&A

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