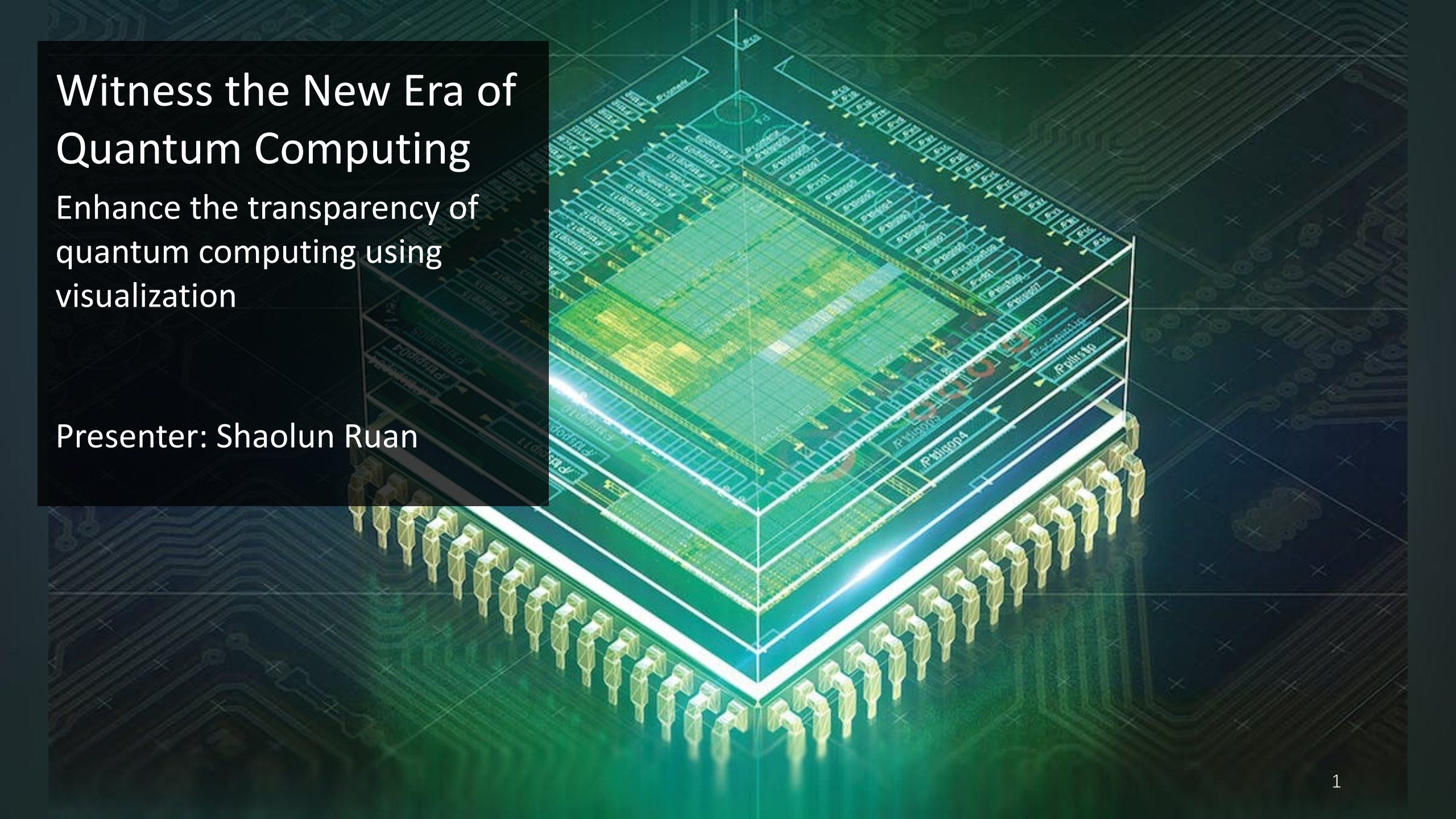
Witness the New Era of Quantum Computing

Enhance the transparency of quantum computing using visualization

Presenter: Shaolun Ruan

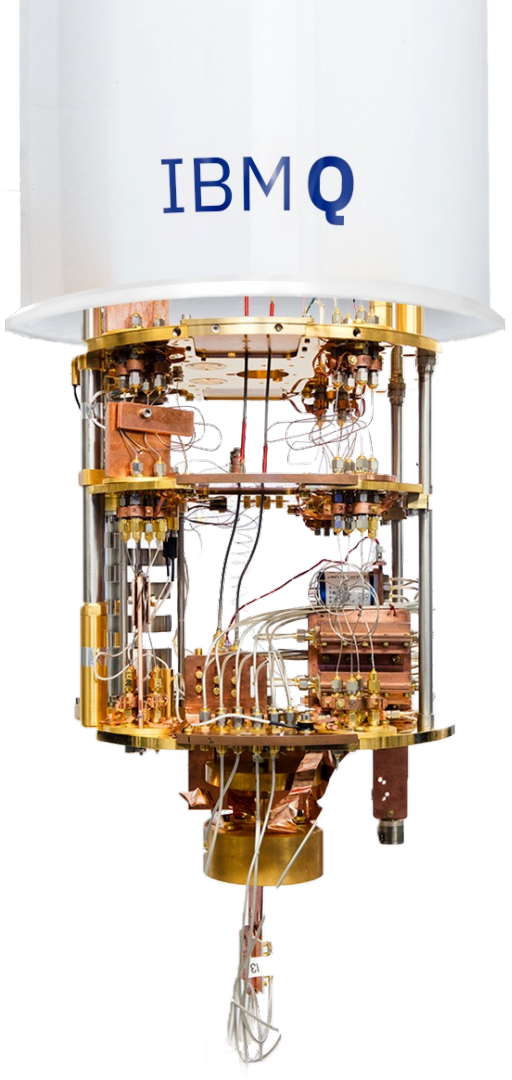


Hi there!

Short Biography

Shaolun RUAN (阮劭伦) is currently a Ph.D. candidate of Computer Science at Singapore Management University, under the supervision of Assistant Professor **Yong WANG**. Before that, he received his bachelor degree from University of Electronic Science and Technology of China majoring in Information Security at School of Computer Science and Engineering in 2019. From 2020 to 2021, he worked as a Research Assistant at Kent State University, U.S.

His major research interests include **Data Visualization**, **Human-Computer Interaction** and **Quantum Computing**.



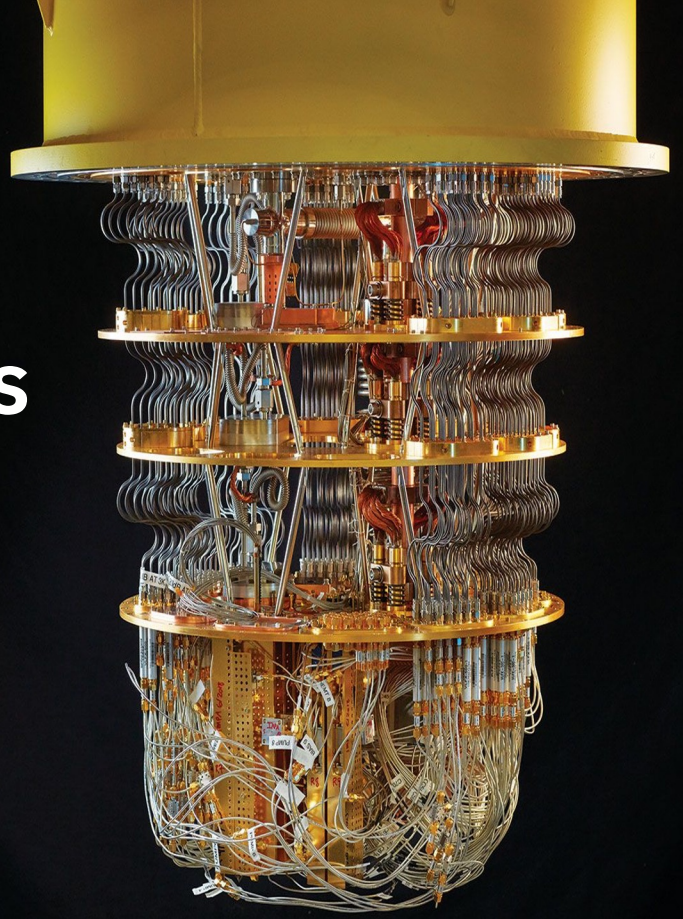
Quantum computers have shown a considerable **speedup over classical computers**

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

15,650 quantum computer physicists were employed in the U.S. in 2015.

90 different types of new job postings for quantum computing commercial jobs in 2018.

https://seedscientific.com/quantum-computing-statistics/



Big IT Companies

- IBM
- Google
- Amazon
- Microsoft
- Intel
- Alibaba

Start-up Companies

- Rigetti
- IonQ
- D-wave
- Xanadu
- Quantum Circuits, Inc.

Quantum Advantages

- Integer Factorization
- Unstructured Search
- Fourier Transform
- etc.

https://qiskit.org/textbook/ch-algorithms/index.html

BLOG ›

Quantum Supremacy Using a Programmable Superconducting Processor

WEDNESDAY, OCTOBER 23, 2019

Posted by John Martinis, Chief Scientist Quantum Hardware and Sergio Boixo, Chief Scientist Quantu
Theory, Google AI Quantum

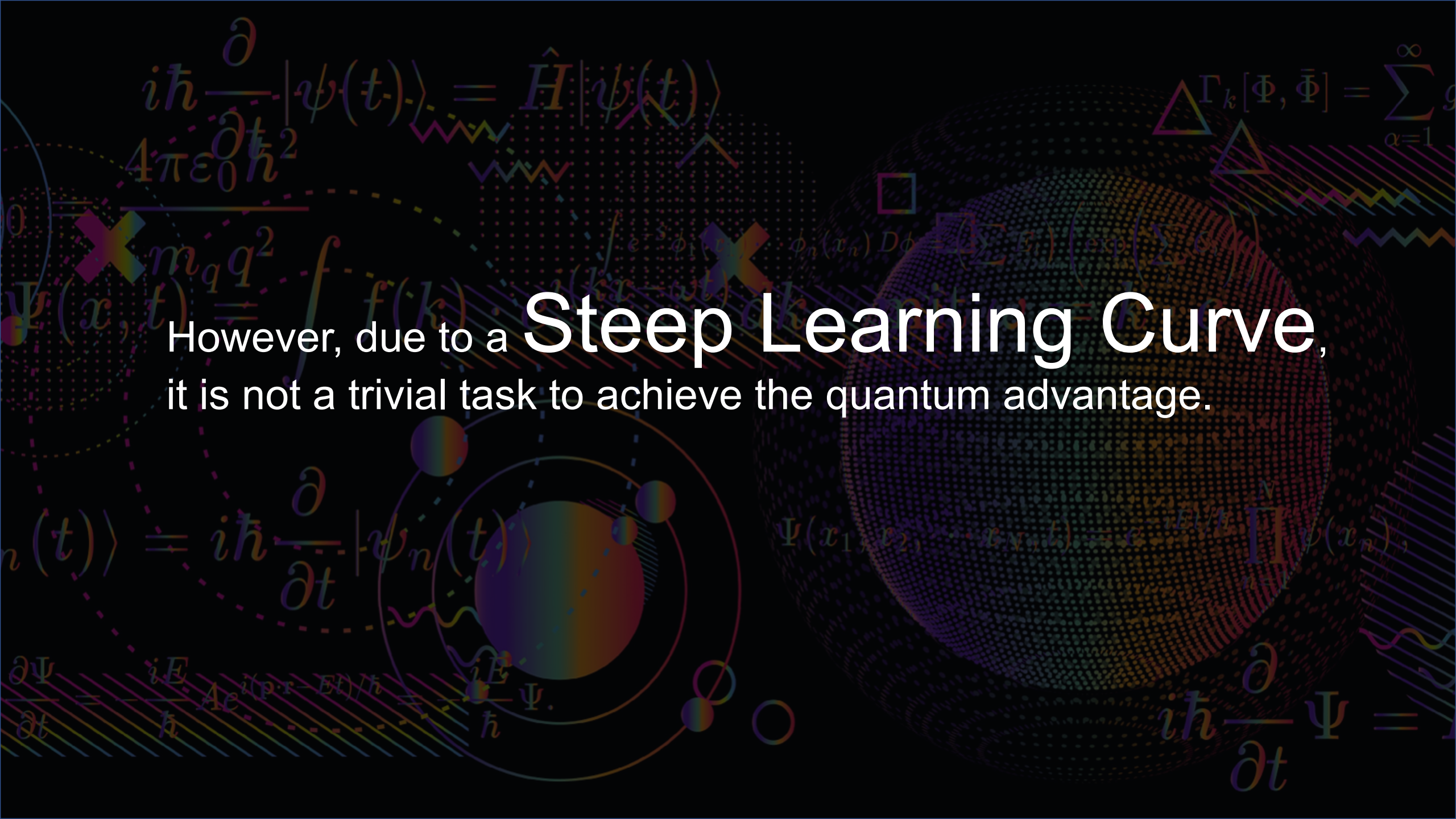
Physicists have been talking about the power of **quantum computing** for over 30 years, but the question
been: will it ever do something useful and is it worth investing in? For such large-scale endeavors it is go
practice to formulate decisive short-term goals that demonstrate whether the designs are going in the rig
So, we devised an experiment as an important milestone to help answer these questions. This experimen
as a **quantum supremacy** experiment, provided direction for our team to overcome the many technical cha
inherent in quantum systems engineering to make a computer that is both programmable and powerful. To
total system performance we selected a sensitive computational benchmark that fails if just a single comp
computer is not good enough.

Today we published the results of this quantum supremacy experiment in the *Nature* article, "**Quantum Supre**
Using a Programmable Superconducting Processor". We developed a new 54-qubit processor, named "Sycan
is comprised of fast, high-fidelity **quantum logic gates**, in order to perform the benchmark testing. Our machin
performed the target computation in 200 seconds, and from measurements in our experiment we determined
would take the world's fastest supercomputer 10,000 years to produce a similar output.

- Quantum Machine Learning
- Quantum Chemistry
- Financial Modelling
- Cybersecurity & Cryptography
- Drug Design & Development
- more…

CEOs of quantum computing companies have noted a lack of trained quantum computer scientists in hiring

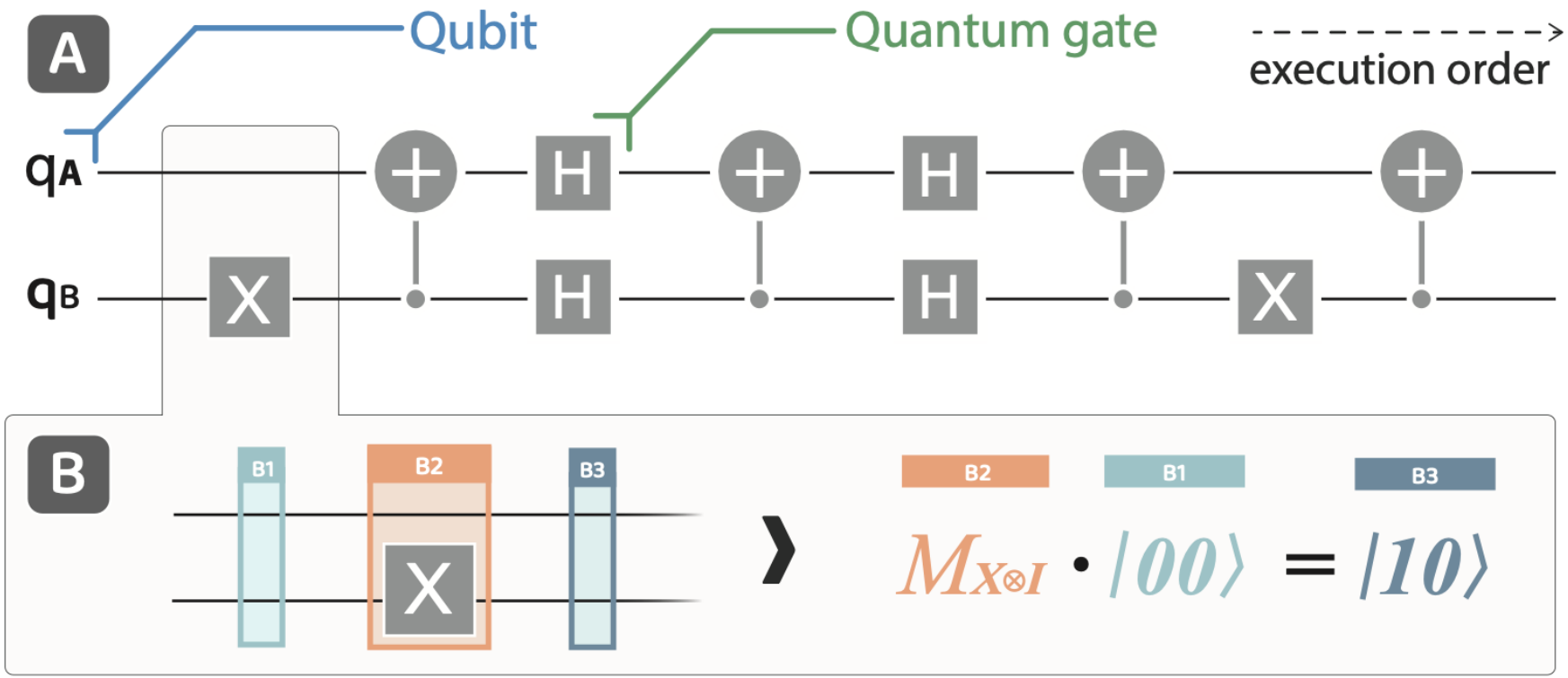
Piattini, M. (2020). Training needs in quantum computing



However, due to a **Steep Learning Curve**,
it is not a trivial task to achieve the quantum advantage.

Quantum computing is hard for people to understand with ease

Quantum computing needs visualization



Quantum circuit

VIS 2022

VACSEN: A Visualization Approach for Noise Awareness in Quantum Computing

Shaolun RUAN — SMU
Yong WANG — SMU
Weiwen JIANG — George Mason University
Ying MAO — Fordham
Qiang GUAN — Kent State University

VIS 2022

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EUROVIS Leipzig 2023

VENUS: A Geometrical Representation for Quantum State Visualization

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Zhepeng WANG — George Mason University
Wei XU — Brookhaven National Laboratory
Yong WANG — SMU

QuantumEyes: Towards Better Interpretability of Quantum Circuits

Shaolun RUAN — SMU
Qiang GUAN — Kent State University
Paul GRIFFIN — SMU
Ying MAO — Fordham
Yong WANG — SMU

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VIOLET: Visual Analytics for Explainable Quantum Neural Networks

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Kent State University

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VACSEN: A Visualization Approach for Quantum Computing

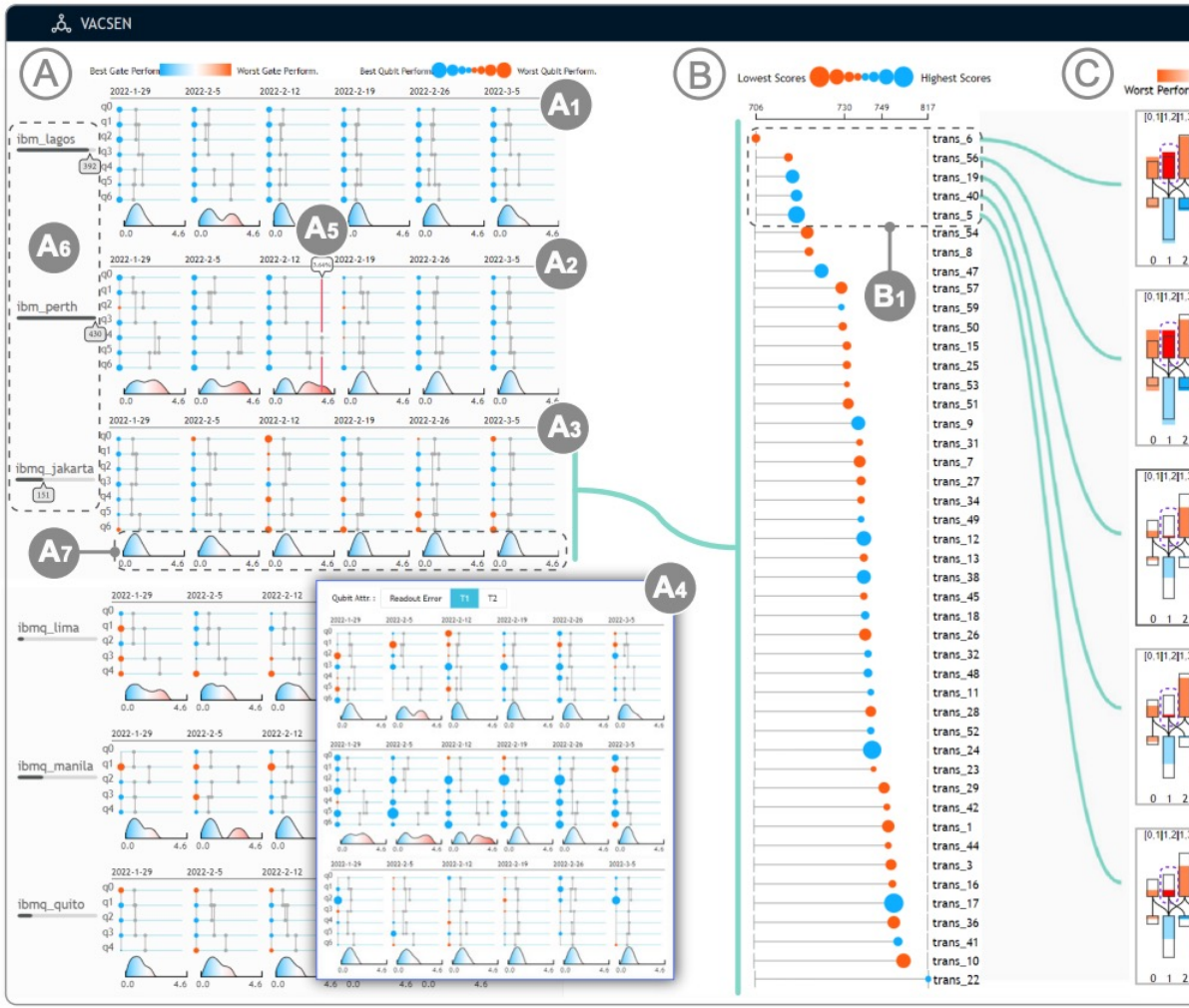
Shaolun Ruan, Yong Wang, Weiwen Jiang, Ying Mao

What's new?

The first tool to make IBMQ users aware of the noise in quantum computers.

So what?

The results' uncertainty can be significantly mitigated in real time.



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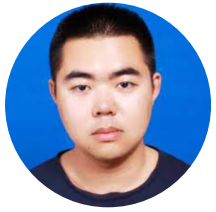

Zhepeng WANG

George Mason University

Wei XU

Brookhaven National Laboratory

Yong WANG

SMU Singapore Management University

Eurographics Conference on Visualization (EuroVis) 2023
D. Archambault, R. Bujack, and T. Schreck
(Guest Editors)

VENUS: A Geometrical Representation Visualization

Shaolun Ruan[1], Ribo Yuan[2,1], Qiang Guan[3], Yanna Lin[4,1], Ying Mao[5], Weiwen Jiang[6],

[1]School of Computing and Information System, Singapore Manageme
[2]Department of Computer and Information Sciences, University of D
[3]Department of Computer Science, Kent State University, U
[4]Department of Computer Science and Engineering, The Hong Kong University of Scie
[5]Computer and Information Science Department, Fordham Unive
[6]Electrical and Computer Engineering, George Mason Universi
[7]Computational Science Initiative, Brookhaven National Laborat

Abstract

Visualizations have played a crucial role in helping quantum computing users explor puting applications. Among them, Bloch Sphere is the widely-used visualization for angles to represent quantum amplitudes. However, it cannot support the visualizatio sition, the two essential properties of quantum computing. To address this issue, we quantum state representation. By explicitly correlating 2D geometric shapes based puting characteristics, VENUS effectively represents quantum amplitudes of both th entanglement. Also, we use multiple coordinated semicircles to naturally encode pro superposition intuitive to analyze. We conducted two well-designed case studies an the usefulness and effectiveness of VENUS. The result shows that VENUS can effect states for the single qubit and two qubits.

CCS Concepts
• ***Human-centered computing*** → *Visualization application domains;* • ***Hardware*** –

What's new?

A novel representation to visualize the quantum states

So what?

The measured probability of basis state can be explained via the amplitudes for single- and two-qubit states.

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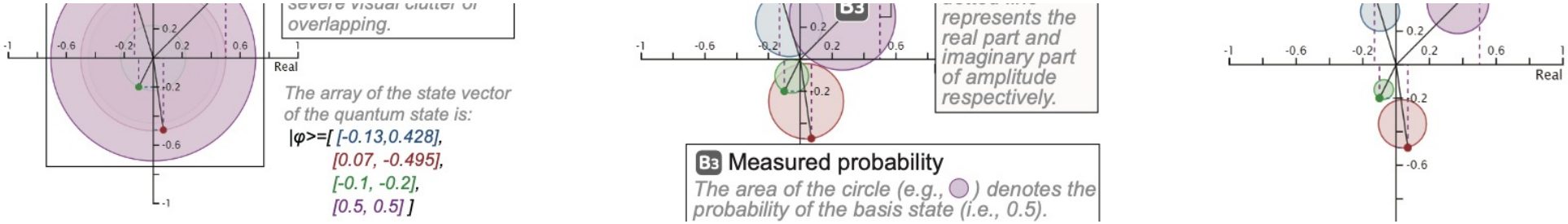

What's new?

A novel VA system to explain the static quantum circuit

+

A novel representation to visualize N-qubit quantum state

So what?

The system can make people better understand the static circuit

+

A novel representation to explain the probability without visual clutter

.

VIOLET: Visual Analytics for Explainable Quantum Neural Networks

Shaolun RUAN

SMU SINGAPORE MANAGEMENT UNIVERSITY

Zhiding LIANG

THE UNIVERSITY OF NOTRE DAME AUSTRALIA

Qiang GUAN

KENT STATE UNIVERSITY

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SMU SINGAPORE MANAGEMENT UNIVERSITY

Xiaolin WEN

SMU SINGAPORE MANAGEMENT UNIVERSITY

Yanna LIN

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Yong WANG

SMU SINGAPORE MANAGEMENT UNIVERSITY

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VIOLET: Visual Analytics for Explainable

Category: Research

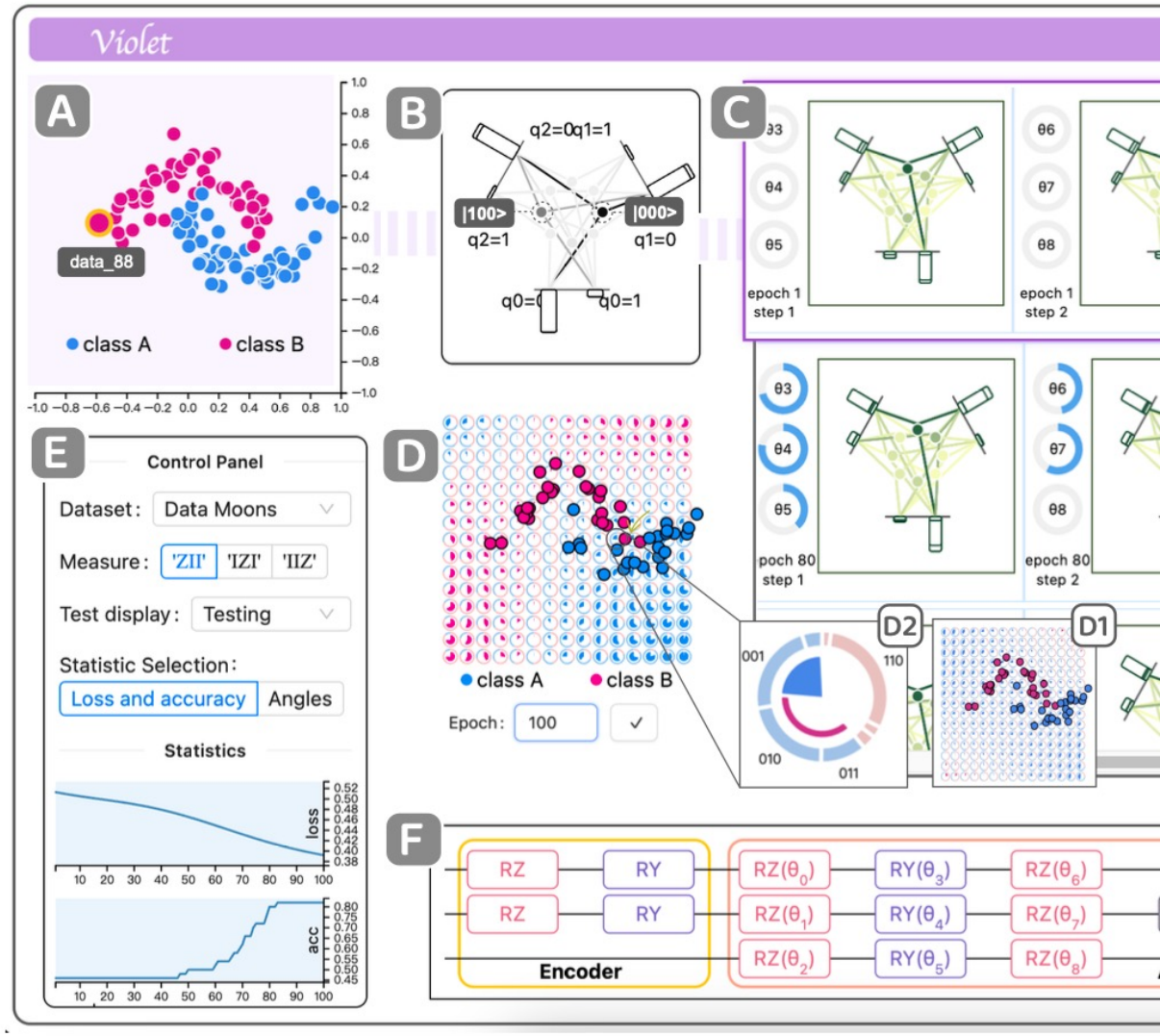
Paper Type: application/design stu

What's new?

The first VA system to visualize quantum neural network

So what?

The three components of QNN can be clearly illustrated and understood with ease



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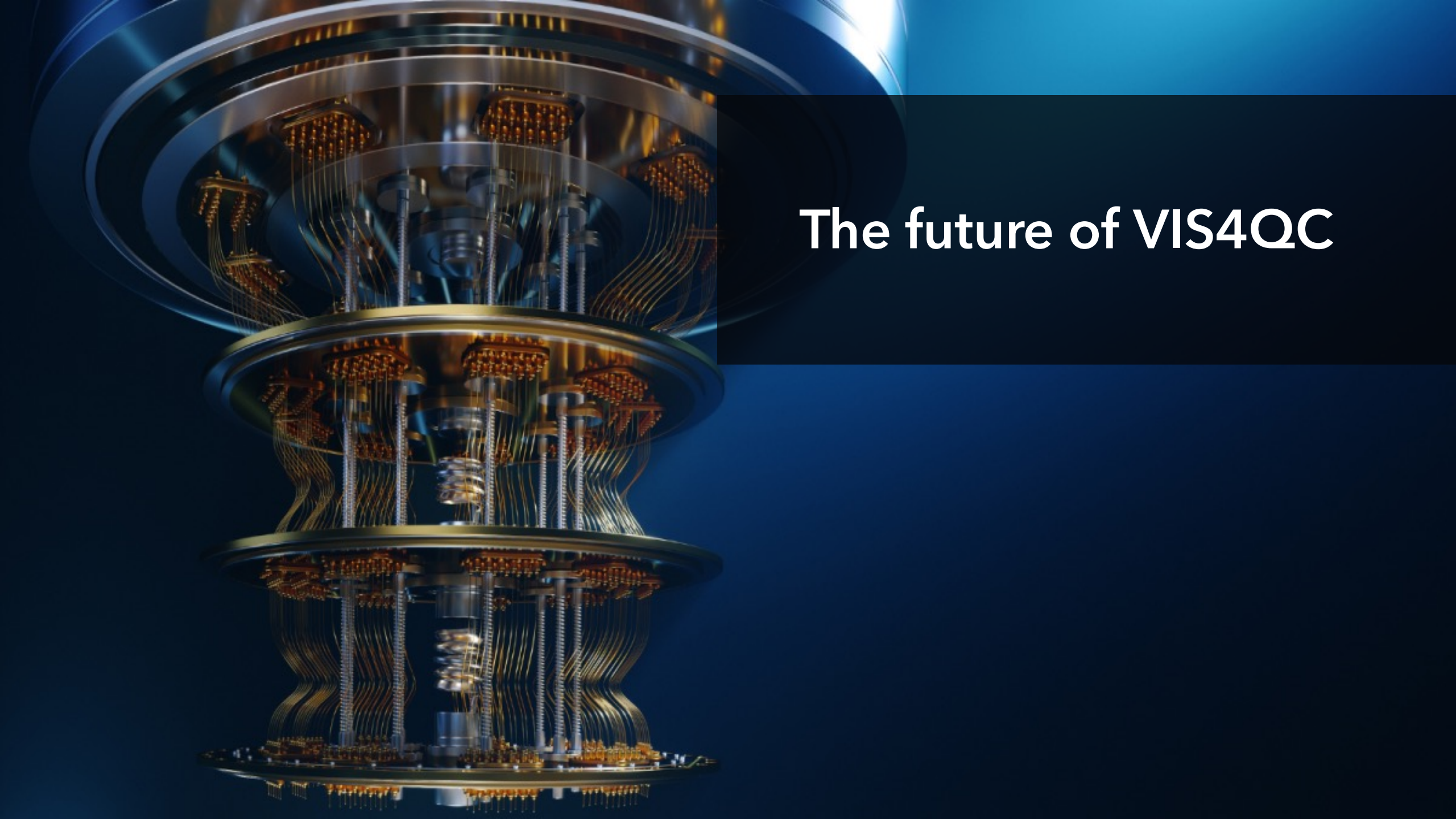

The future of VIS4QC

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Editor's Comments:

Associate Editor
Comments to the Author:
This paper is a VIS resubmission, and consequently the reviewers of the original submission were invited to referee the manuscript. Two reviewers accept as is, while two argue for minor revisions.

The reviewers commend the authors on the rigorous effort put into addressing the previous comments, and on the excellent response to the reviews. The is a strong contribution in an under-explored application area, hence I recommend Acceptance; congratulations!

All reviewers point out fairly minor issues with copy-editing, formatti that should be corrected for a final version of the paper. However, in while these corrections serve to improve the paper, they do not req review cycle (even a minor one). Hence, I strongly encourage the a consult the reviews and address these comments for a final subm

Acceptable

The Summary Review (Due by May 14)

All reviewers confirm that this is a good paper. The scores from reviewers are very positive. We are happy to see such a good work in the conference.

The authors should carefully read the reviews and incorporate the reviewers' comments in their revision.

Strengths:
+ Quantum computing is a new appli
+ The work would

accepted.

The work is highly relevant to the VIS community as it deals with a challenging application for which visual representations and analysis hold promise to assist both in fundamental understanding of quantum gates and circuit functionality as well as development of algorithms.

My only concern is that the presented visual representations do not scale well to more complex problems and the authors are thus encouraged to continue the work on higher level of abstractions to assist algorithm development in the future. I am very happy to see that visualization enters into the era of quantum computing and this paper is a good example of that.

A minor comment is that I would ask the authors to change the font in the video. White on white is hard to read.

Additional Questions:
1. Which category describes this manuscript?: Application

Blue Ocean of VIS4QC

- Application-based
  - Quantum finance, quantum chemistry, etc.
  - Q-CNN, Q-GAN, Q-RNN, etc.
- User interaction enhancement
  - Document enhancement of online tutorial
  - Transfer non-intuitive QASM code to graphical representation
- Explanability
  - Quantum-specific angles like barren plateau, expressibility of QNN
  - Traditional-inspired ideas like education purpose, what-if analysis, etc. approaches for QNN
- Speedup for traditional visualization
  - Graph drawing
  - Visualization recommendation
  - Others…

Be part of VIS4QC!

In 2016, visual analytics step into the era of deep learning.
Let’s embrace the next generation of visualization community!

Thank you for your attention!