ASPLOS Tutorial 2024

Janus 2.0: A Software Framework for Analyzing Optimizing and Implementing Quantum Circuit

Organizers: **Jianwei Yin**, Liqiang Lu, Siwei Tan

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Zhejiang University (ZJU)

https://janusq.github.io/tutorials/

Self-introduction

Jianwei Yin

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Dr. Jianwei Yin is a full professor at the College of Computer Science, Zhejiang University. He is the dean of the School of Software Technology. His interests lie in advanced computing and service computing and has published more than 300 papers in top international journals and conferences such as ASPLOS, MICRO, HPCA, DAC, VLDB, ICDE, TC, TSE, TKDE, TPDS, et al. He led the setup of two international standards and won many Best Paper Awards, such as ICSOC 2017 and ICWS 2019.

- Dean of School of Software at Zhejiang University
- Director of Development & Planning Department of Z

Organizers

Jianwei Yin

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Liqiang Lu

Assistant professor

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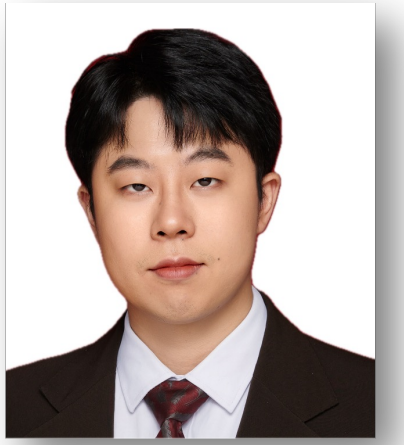


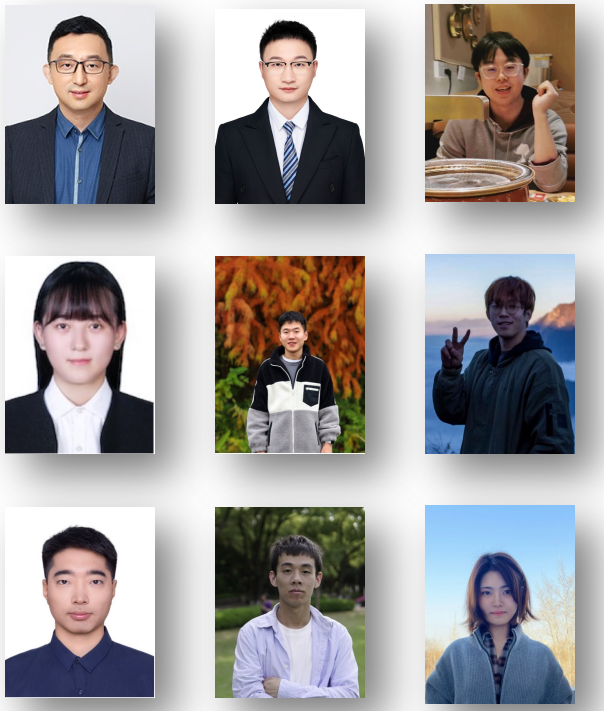
Siwei Tan

5-year PhD student

siweitan@zju.edu.

Advanced Computing and Emerging Service Lab

ACES Lab
ADVANCED COMPUTING AND EMERGING SERVICE LAB



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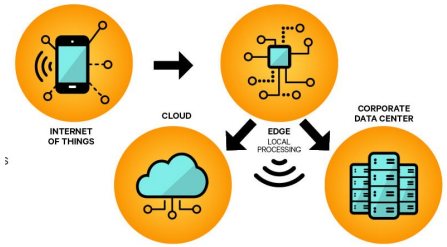
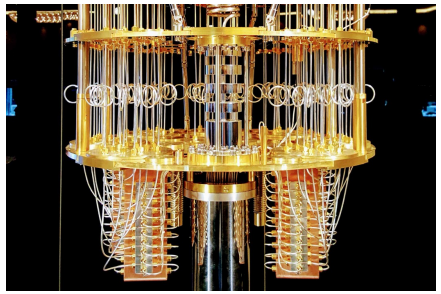
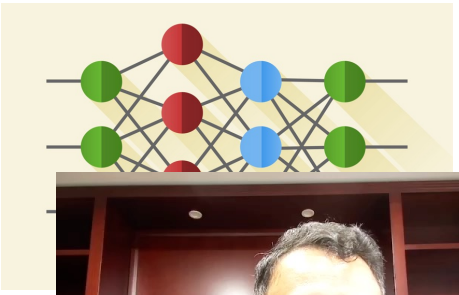
Advanced Computing and Emerging Service Lab (ACES Lab) in Zhejiang University is led by Professor Yin Jianwei. It consists of 28 faculty members and 170 students from the College of Computer Science and Technique, Zhejiang University. The laboratory focuses on **quantum computing, edge computing, and artificial intelligence**, as well as emerging services enabled by these advanced computing technologies.



Service computing



Quantum computing



A

Milestone of Janus Quantum

The founding of Janus Quantum

ACES

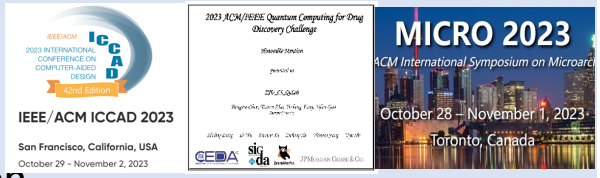
JanusQ Software 2.0

- Cluster I/O
- Quantum compilation

JanusQ Software

Many achievements were published in top conferences

- ICCAD & MICRO
- ICCAD quantum chemistry competition



2021/1

2022/7

2022/12

2023/2

2023/10

2024/4

Taiyuan-1 Quantum Cloud Platform

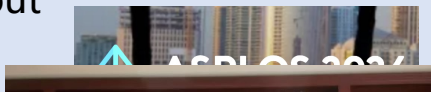
The first computational visualization and distributed scheduling platform.

Hybrid quantum-classical SAT solver

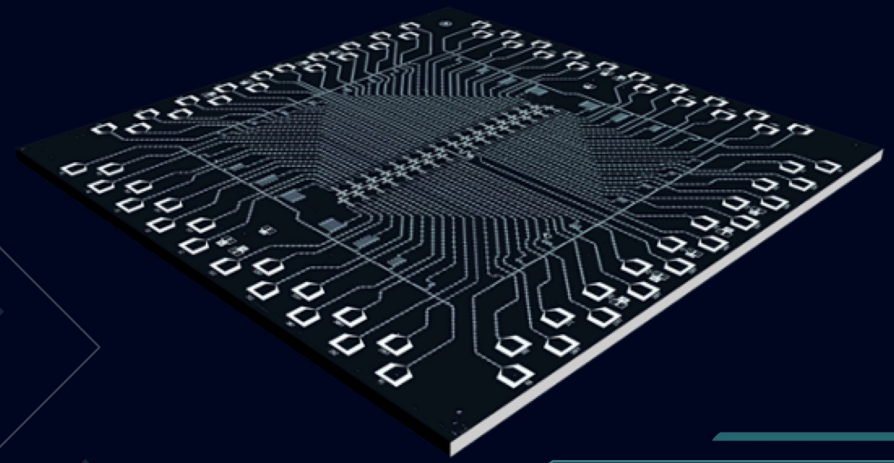
Revealed with JanusQ cloud in HPCA 2023

ASPLOS & Janus 2.0 tutorial

- Ultra-fast readout calibration
- China's first quantum tutoria

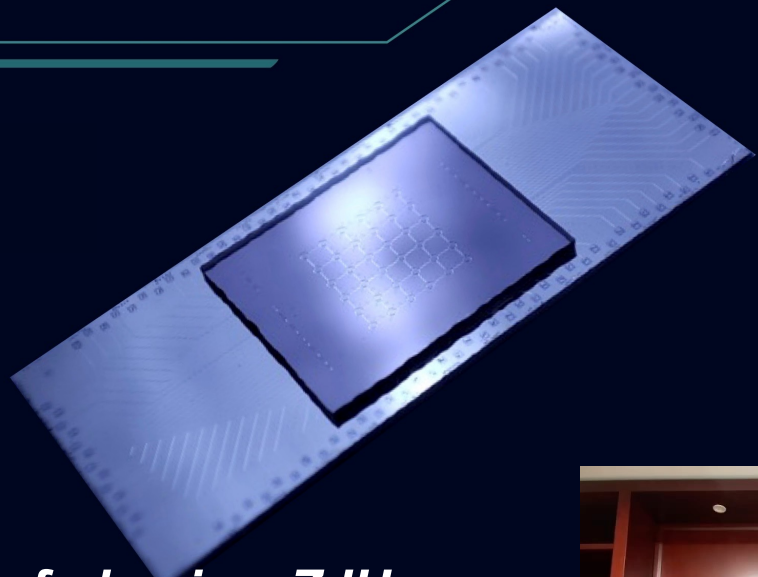


Quantum Processor on JanusQ



Mogan

32 qubits/ 30μs relaxation time / Fully connected topology



Tianmu

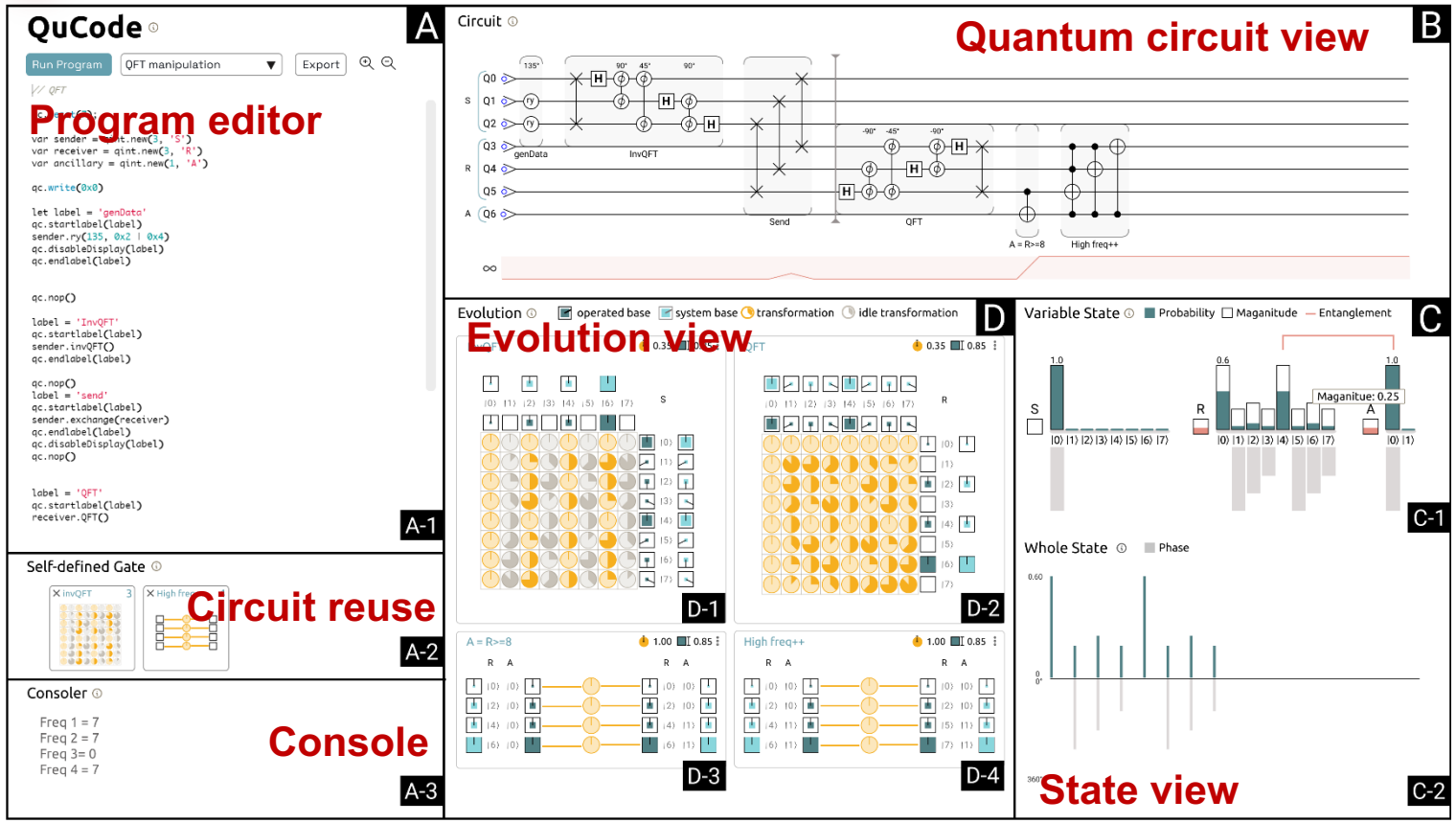
36 qubits/ 100μs relaxation time/
60ns two-qubit gate time
CZ gate fidelity: 99%

Collaborate with the department of physics, ZJU

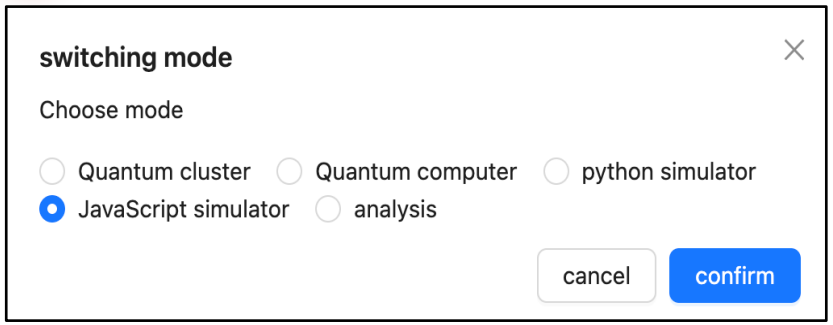
JanusQ Quantum Cloud

ZHEJIANG UNIVERSITY

Coding interface of JanusQ



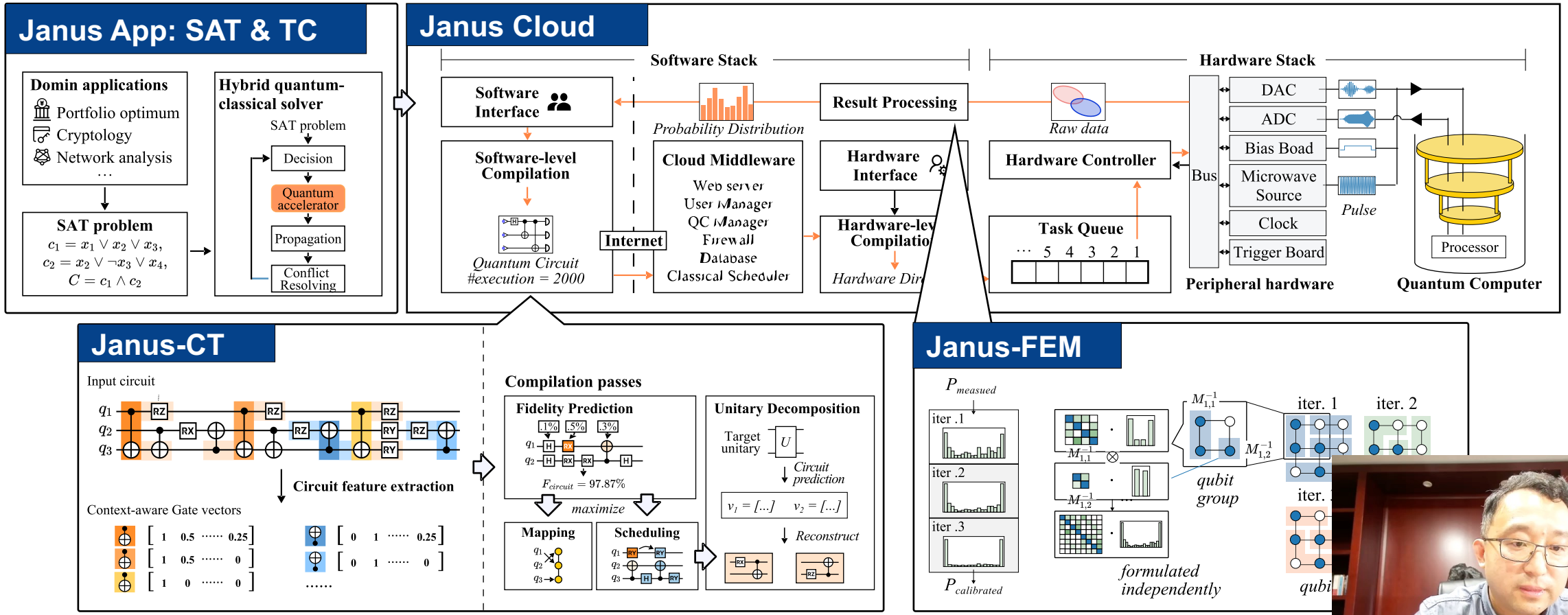
Execution modes



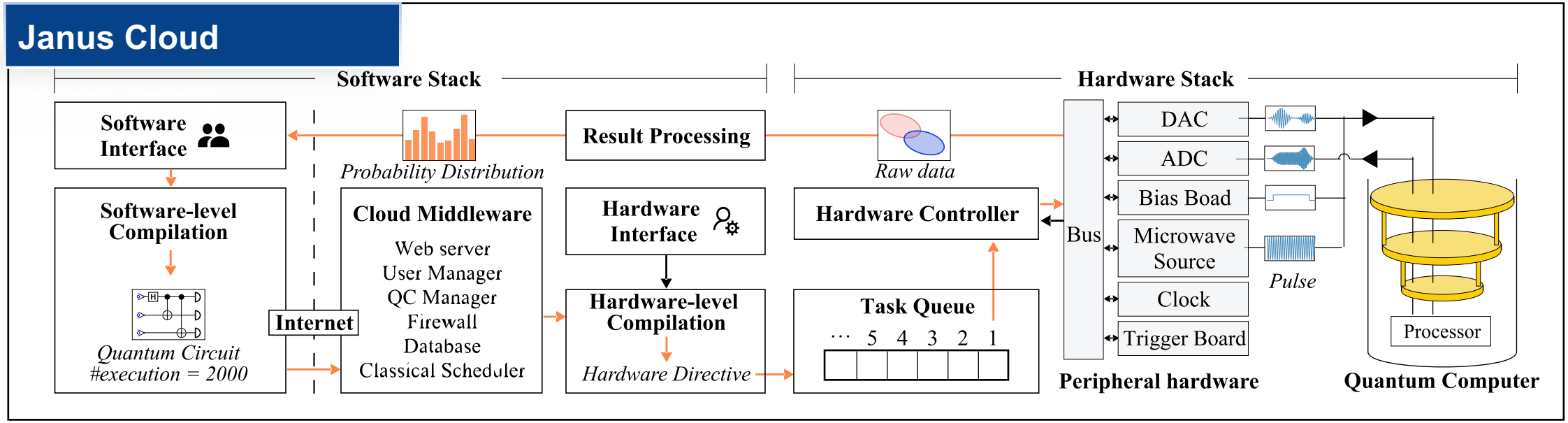
Provided quantum processors

JanusQ Overview

Janus 2.0: A Software Framework for Analyzing Optimizing and Implementing Quantum Circuit



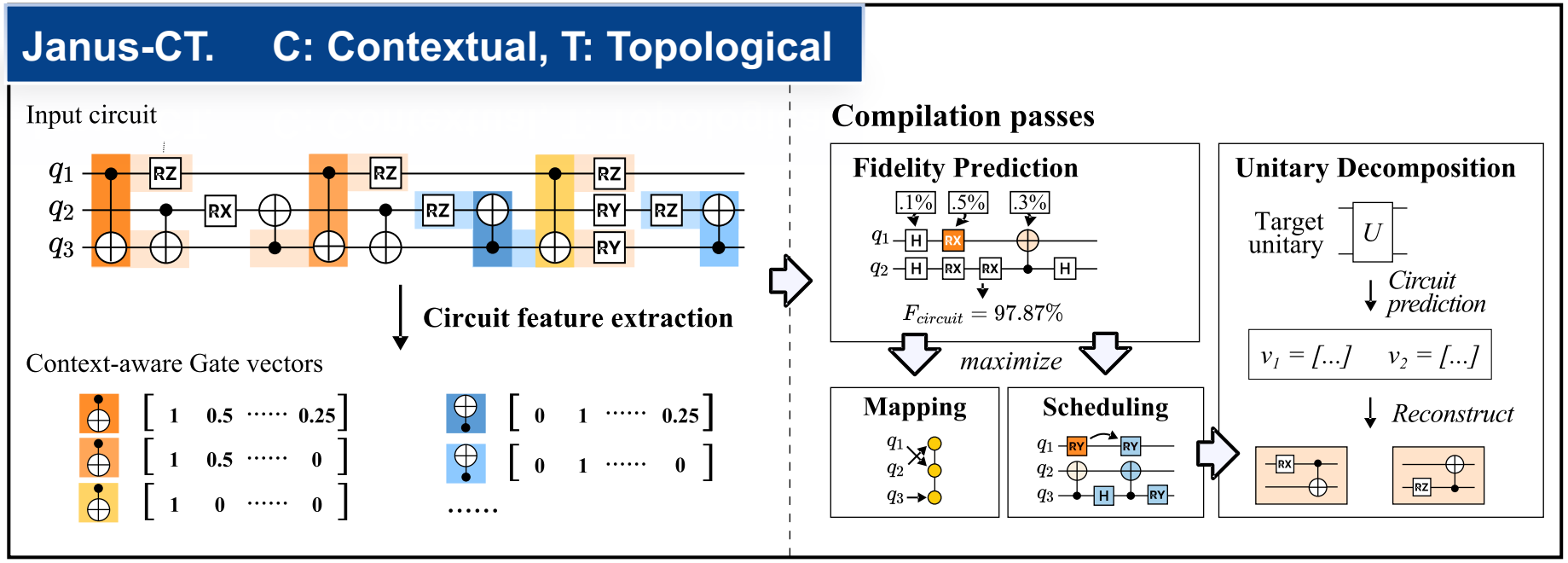
JanusQ Overview



Janus Quantum Infrastructure:

- How do you use the code editor on the cloud platform?
- How do we submit the task to quantum hardware via API?
- How do we take advantage of JanusQ architecture?

JanusQ Overview



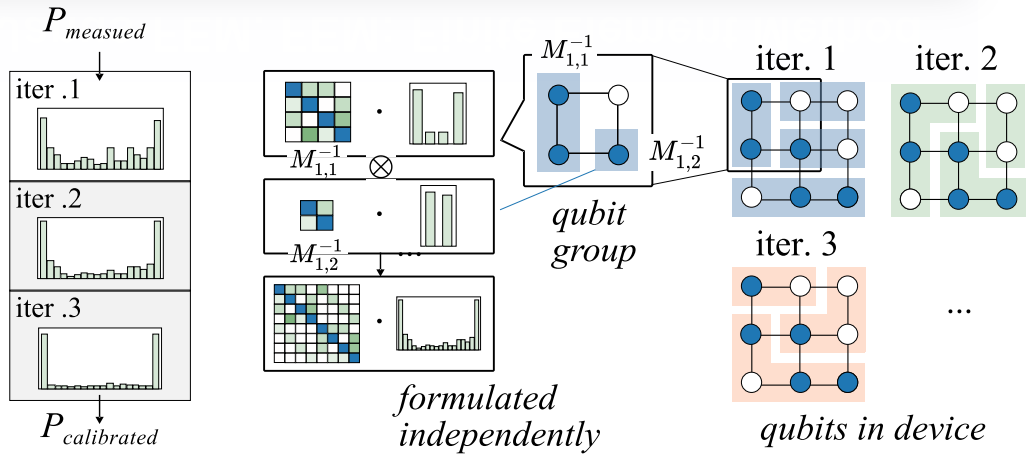
Janus-CT: Topology-aware quantum circuit optimizer (MICRO 2023)

- Why is topological information important in circuit analysis and optimization?
- How do we use topological information to analyze and optimize noise?
- How can we speed up the unitary decomposition with an upstream model?

Related papers: QuCT: A Framework for Analyzing Quantum Circuit by Extracting Contextual and Topological Features. **[MICRO 2023]**

JanusQ Overview

Janus-FEM. FEM: Finite Element Method

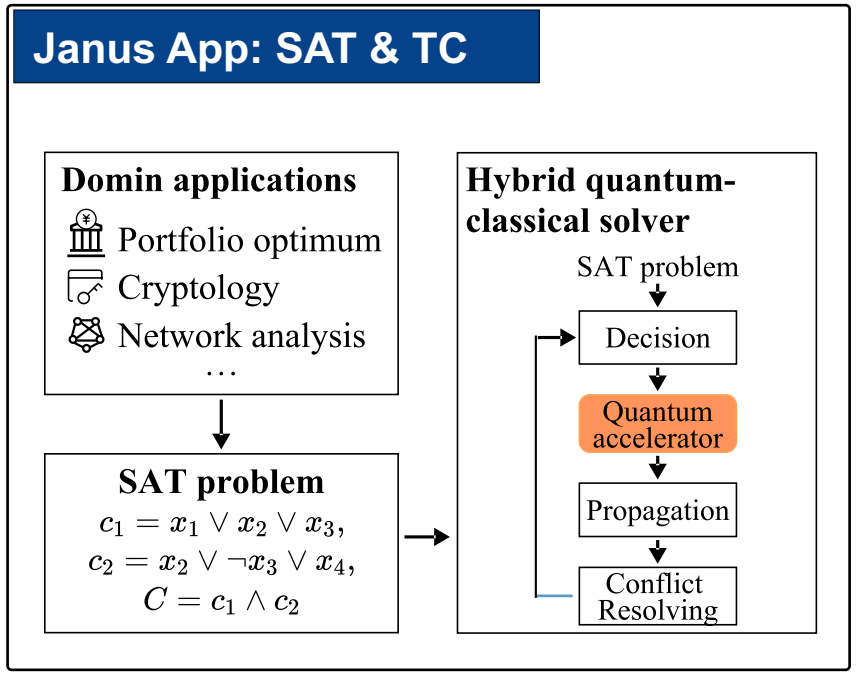


Janus-FEM: Readout Calibration based on finite element method (ASPLOS 2024)

- What is readout error and the difficulty of calibrating it?
- What is the finite element method?
- How do we mitigate the readout noise using the finite element method?

Related papers: QuFEM: Fast and Accurate Quantum Readout Calibration Using the Finite Element Method. **[ASPLOS 2024]**

JanusQ Overview



Janus-SAT: Hybrid Quantum-Classical SAT solver (HPCA 2023)

- What is the SAT problem? Why is it important?
- How to achieve 4.2× end-to-end speedup compared to the state-of-the-art SAT solver?

Janus-TC: Topological Time Crystal (Nature 2022)

- What is time crystal?
- How can a topological time crystal with high fidelity be simulated on JanusQ Cloud?

Related papers:

HyQSAT: A Hybrid Approach for 3-SAT Problems by Integrating Quantum Annealer with CDCL. **[HPCA 2023]**

Digital quantum simulation of Floquet symmetry-protected topological phases. **[Nature 2022]**

Outline

Topic	Presenter	Time
Topic-1. Overview of JanusQ 2.0 and Background of Quantum Computing	Jianwei Yin	0.25 hour
Topic-2. Installing JanusQ 2.0 and Using Janus quantum cloud platform	Siwei Tan	0.75 hour
Topic-3. Janus-CT to optimize (a) Vectorization model using Janus-CT and code examples (b) Fidelity optimization using gate vectors (c) Unitary decomposition using gate vectors (d) Extending the framework by yourself: other downstream tasks!	Liqiang Lu	(1.0 hour) 0.25 hour 0.25 hour 0.25 hour 0.25 hour
Take a break		0.25 hour
Topic-4. Janus-FEM (a) Characterization of readout error (b) Readout calibration using Janus-FEM	Hanyu Zhang	(0.5 hour) 0.25 hour 0.25 hour
Take a break		0.25 hour
Topic-5. Implementing quantum applications (a) Introduction of SAT problem and time crystal (b) End-to-end speedup in domain problems based on quantum SAT solver (c) Simulate time crystal on the Janus quantum platform	Siwei Tan	(1.25 hour)
Topic-6. Q & A	Siwei Tan	
Total		

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Thanks !