JUNIQ Benchmark Suite

A Decade of Application Benchmarks on Quantum Computers

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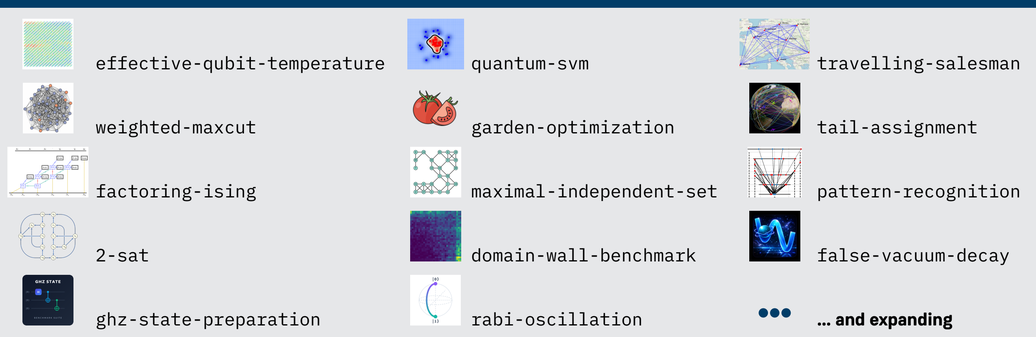
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MOTIVATION

We present the **JUNIQ Benchmark Suite (JBS)**, a large collection of benchmark problems and a free and open-source framework designed to track the performance of quantum processing units (QPUs) on application-driven problems. We provide:

1. **Long-term Progress Tracking (since 2016):** An archive that tracks technology readiness across diverse QPU modalities and hardware generations, from early prototypes to future fault-tolerant systems.
2. **Beyond Abstract Metrics:** Shift focus from synthetic metrics (e.g. gate fidelity) to vendor-agnostic application-driven problems that demonstrate **real-world utility**.
3. **Reproducibility & Standardization:** A standardized workflow to validate performance claims across diverse QPU architectures.

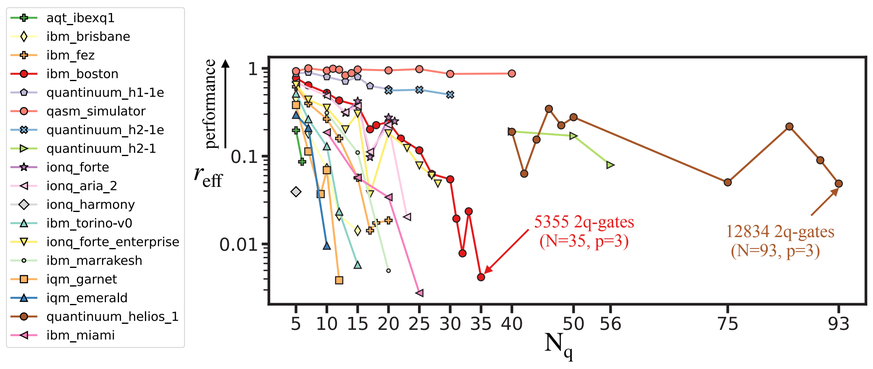
BENCHMARK SUITE OVERVIEW



TRACKING QPU PROGRESS

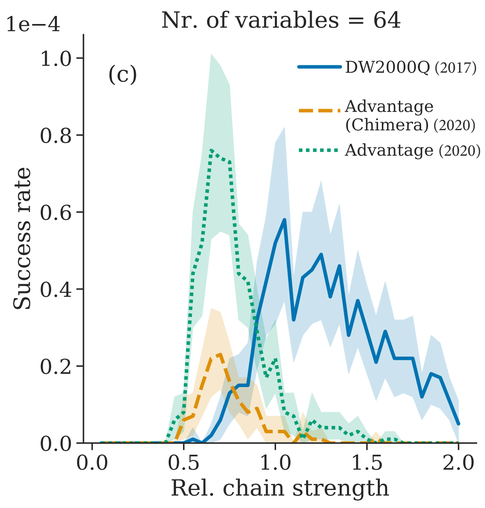
Across Systems and Sizes (LR-QAOA)

Benchmarking 30 QPUs with MaxCut problems using LR-QAOA [1].



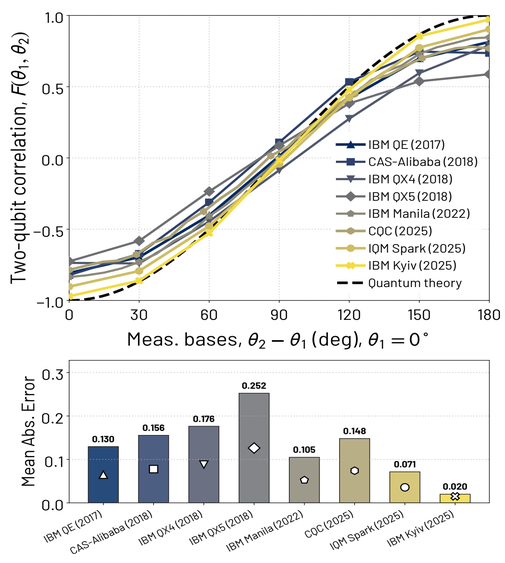
Across Generations

D-Wave performance over successive generations solving Garden Optimization problems [2].



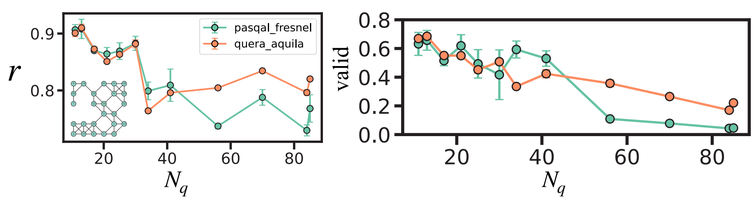
Closeness to Quantum theory

QPU comparison for singlet-state experiments [3].



Across Modalities (MIS-QAA)

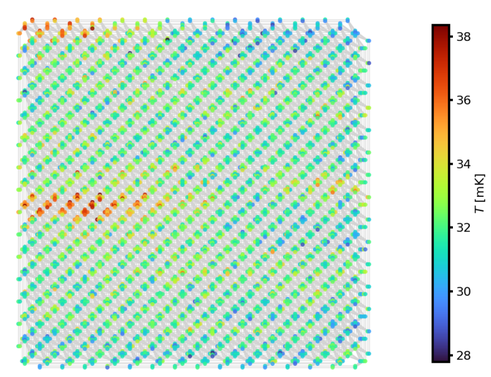
Benchmarking neutral atom-based quantum processors at scale [4].



SELECTED BENCHMARKS

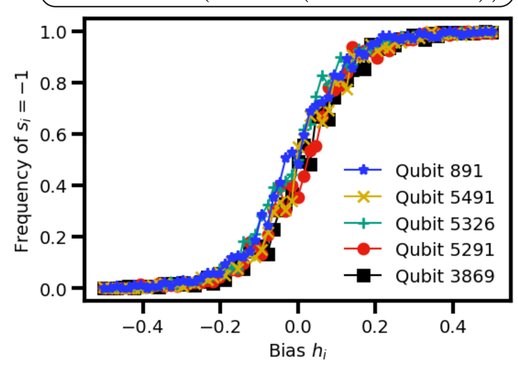
Effective Qubit Temperature [Hardware Diagnostics]

Determining the effective temperature (T) for each qubit by fitting a Boltzmann distribution to the experimental data.



Distribution of T across qubits on Advantage_system4.1 as on 2022-03-01.

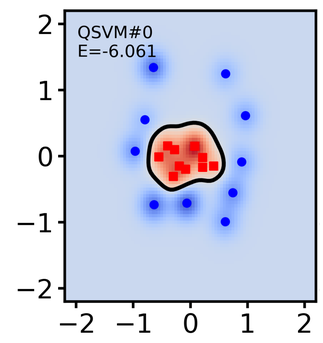
$$p(s_i = -1) = \frac{1}{2}\left(1 + \tanh\left(\frac{B(1)}{2k_B T}(h_i - h_{\text{offset}})\right)\right)$$



Experimental results for a few qubits.

Quantum Support Vector Machines [Machine Learning & Sensing]

QSVMs classify data via high-dimensional feature space mapping, applied to biological sequence analysis and remote sensing [5].



Classification [5]



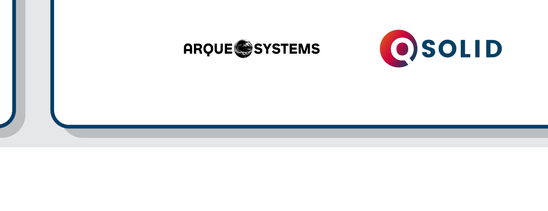
DNA Binding Prediction [5]



Multiclass SVM [6]

Travelling Salesman Problem [Optimization & Logistics]

Shortest route visiting each city once and returning [7, 8].



Optimization of a route across a subset of European cities.

REFERENCES & ACKNOWLEDGEMENTS

Find out more about JBS

go.fzj.de/
juniq-benchmark-suite-page

Papers

[1] J. A. Montañez-Barrera et al. *arXiv:2502.06471* (2025).

[2] C. D. Gonzalez Calaza et al. *Quantum Inf. Process.* **20**, 326 (2021).

[3] K. Michielsen et al. *Comput. Phys. Commun.* **220**, 44 (2017).

[4] A. B. Rava et al. *arXiv:2511.22967* (2025).

[5] D. Willsch et al. *Comput. Phys. Commun.* **248**, 107006 (2020).

[6] A. Delilbasic et al. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* **17**, 1434 (2024).

[7] J. A. Montañez-Barrera et al. *Quantum Sci. Technol.* **9**, 025022 (2024).

[8] D. Willsch et al. *Quantum Inf. Process.* **21**, 141 (2022).

Acknowledgements

D-Wave · eleQtron · Jülich JUNIQ · IQM · HPCQS · Helmholtz Research for Grand Challenges · Pasqal · OpenSuperQPlus · GCS Gauss Centre for Supercomputing · ARQUE Systems · SOLID · Bundesministerium für Forschung, Technologie und Raumfahrt