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AI and Quantum Research Center (AIQRC), Asia University, Taiwan

Activity

[1] Dec. 5, 2025. Professor Ka-Lok Ng delivered a presentation at the National Science Council's Smart Computing Research Achievements Meeting, held in Room A116 at Asia University.

Title: Realizing Quantum Advantage with Quantum Machine Learning for Biomedical Data Classification

[2] Nov. 27, 2025. AIQRC has signed a Memorandum of Understanding (MOU) to partner with a local instrument manufacturer.

Breakthrough in Quantum Simulation: JUPITER Achieves Full 50-Qubit Universal Quantum Computer Simulation

Researchers at the Jülich Supercomputing Centre, in collaboration with NVIDIA, have achieved a historic milestone in quantum technology by successfully simulating a **universal 50-qubit quantum computer** on Europe's first exascale system, **JUPITER**. This accomplishment sets a new world record in classical quantum simulation and demonstrates the accelerating intersection of high-performance computing and quantum algorithm research.

Simulating universal quantum circuits is one of the most computationally demanding tasks known, as the quantum state of an *n-qubit* system grows exponentially, represented by **2^n complex amplitudes**. Reaching 50 qubits requires approximately **2 petabytes** of memory—far beyond the capability of conventional computing systems. The JUPITER architecture, equipped with NVIDIA GH200 Grace Hopper Superchips, enabled the team to overcome this barrier through a combination of hybrid memory offloading, data compression, and large-scale system coordination.

Hybrid CPU–GPU Architecture Enables Large-Scale Quantum State Simulation

A key factor in this breakthrough is the GH200 Superchip, which tightly integrates GPU acceleration with high-bandwidth CPU memory. Traditional GPU memory is insufficient to hold 50-qubit state vectors, but the GH200 architecture allows seamless offloading between GPU and CPU memory without significant performance loss.

The research team upgraded the Jülich Universal Quantum Computer Simulator (JUQCS) to a specialized version, **JUQCS-50**, designed to exploit this heterogeneous memory system. JUQCS-50 can maintain high-fidelity simulation even when the quantum state exceeds GPU memory, thanks to optimized memory traffic and asynchronous communication between compute nodes.

Additionally, the system employed a **byte-encoded compression technique**, reducing memory requirements by nearly eightfold. This approach minimizes the memory footprint while retaining accuracy during gate operations, enabling large circuits to be simulated within the physical limits of the JUPITER system.

Dynamic Data-Exchange Algorithms for Scaling Across 16,000+ Nodes

Another major innovation was the development of a dynamic algorithm that manages data distribution and communication across **more than 16,000 GH200 nodes**. Quantum gate operations on a 50-qubit state require updating over **2 quadrillion amplitude values**, which must be synchronized across thousands of processors.

The new communication strategy dynamically tracks data placement and reallocates workloads in real time, reducing communication latency and ensuring efficient use of system bandwidth. This approach provides the scalability needed to simulate larger qubit counts and more complex quantum circuits.

Implications for Quantum Algorithm Research

The ability to simulate 50 qubits with full state fidelity has broad implications for near-term quantum algorithm development. Many algorithms—such as the QSVC, VQE, QAOA, andvquantum chemistry solvers—cannot currently be executed on physical hardware due to noise and limited qubit counts.

JUQCS-50 serves as a high-accuracy validation environment, enabling researchers to:

- Test quantum circuits at scales beyond today's hardware
- Benchmark quantum advantage claims
- Perform noise-free comparisons for hybrid algorithms
- Explore quantum circuit performance under idealized conditions
- Support hardware-software co-design for next-generation quantum processors

This capability is particularly valuable for the global research community working toward quantum-classical hybrid technologies, where classical simulation remains essential for verifying algorithmic correctness and behavior.

Integration into JUNIQ and Future Directions

JUQCS-50 will be made available through **JUNIQ**, the Jülich Unified Infrastructure for Quantum Computing. This integration allows external academic researchers, industry groups, and national laboratories to access exascale-level quantum simulation resources.

As quantum hardware scales toward fault tolerance, the JUPITER simulation results provide insights into memory layouts, circuit depth limits, and algorithmic complexity thresholds. The work also establishes a clear scaling roadmap, suggesting that simulations beyond 50 qubits may soon become feasible through improved compression, multi-GPU tiling, and next-generation exascale nodes.

Overall, this achievement demonstrates the increasing synergy between quantum technologies and advanced classical computing, marking a critical step toward enabling realistic, high-fidelity quantum experimentation at scales unattainable on today's quantum hardware.

References

1. Hans De Raedt, Jiri Kraus, Andreas Herten, Vrinda Mehta, Mathis Bode, Markus Hrywniak, Kristel Michielsen and Thomas Lippert, Universal Quantum Simulation of 50 Qubits on Europe's First Exascale Supercomputer Harnessing Its Heterogeneous CPU-GPU Architecture", 7 Nov 2025, arXiv DOI:10.48550/arXiv.2511.03359

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