HYUNSEONG KIM

Quantum Algorithms | Computational Complexity | Hamiltonian Simulation

Houston, TX | hyunseong252@gmail.com | github.com/HYUNSEONG-KIM

hyunseong-kim.github.io | LinkedIn | ORCID: 0000-0002-4876-7820

RESEARCH PROFILE

Ph.D. student in Applied Physics in the Quantum Complexity Theory research group at Rice University, advised by Nai-Hui Chia. Research focuses on quantum algorithms, quantum circuit complexity, and Hamiltonian simulation, including circuit-depth and sampling-complexity analysis, perturbation bounds, and numerical stability. Experience independently developing algorithms and implementing research software in Python and C.

EDUCATION

Rice University Houston, TX

Ph.D. in Applied Physics 2025 - Present

Advisor: Nai-Hui Chia | Expected graduation: 2029

Gwangju Institute of Science and Technology (GIST) Gwangju, South Korea

B.S. in Physics and Photonics; Minor in Mathematics 2019 - 2025

Undergraduate thesis: *Trotter Circuit Optimization on Gate-Model Quantum Computers and Applications.*

RESEARCH EXPERIENCE

Rice University | Quantum Complexity Theory Group 2025 - Present

Ph.D. Researcher | Advisor: Nai-Hui Chia

- Study quantum circuit complexity, including constant-depth constructions, unitary designs, and scrambling.
- Investigate hybrid quantum algorithms for Hamiltonian dynamics using Krylov-subspace methods; analyze circuit depth, sampling complexity, and classical computational cost.
- Analyze perturbations, error propagation, and numerical stability in Gram-matrix estimation, reduced Hamiltonians, and observable estimation.
- Build numerical prototypes in Python and PennyLane to support quantum-algorithm research and resource analysis.

SELECTED ALGORITHM & SOFTWARE PROJECTS

Tensorized Pauli Composer | Author & Developer GitHub

- Developed an algorithm for constructing Hamiltonian matrices from weighted Pauli polynomials using symplectic representations and inverse tensorized Pauli decomposition.
- Independently designed and implemented the algorithm before integrating it into OptTrot.
- Released implementation and benchmark materials with a Zenodo technical preprint; presented the work as a poster at Quantum Threads 2024.

OptTrot | Core Developer GitHub

- Designed and implemented routines for Pauli-group algebra, Hamiltonian decomposition, Pauli-polynomial manipulation, operator conversion, and Trotter-circuit generation.
- Implemented compact symplectic and bit-string Pauli representations in C, exposing low-level routines through Python APIs.
- Benchmarked 12-qubit Pauli-polynomial matrix construction: **3.48 s versus 33.2 s for Qiskit** in the reported test configuration; benchmark implementation and data are available in the project repository.

ADDITIONAL RESEARCH EXPERIENCE

The two GIST research appointments below were held concurrently.

GIST | Quantum Field and Gravity Theory Group Jul 2023 - Dec 2024

Research Intern | Gwangju, South Korea

- Investigated quantum-information and complex-system problems, including transformations between commuting stabilizer frames and Pauli-frame representations.
- Studied random-matrix and machine-learning models for complex physical systems; organized a weekly quantum-information seminar.

GIST | Computational Materials Science Laboratory Oct 2023 - Dec 2024

Research Intern | Gwangju, South Korea

- Investigated gate-model quantum simulation, including quantum tunneling-time estimation and computational frameworks for quantum-simulation problems.

Korea University | Quantum Workforce Center Jul 2023 - Aug 2023

Research Intern | Seoul, South Korea

- Developed Trotter-circuit optimization methods using adiabatic optimization and implemented gate-model quantum simulation workflows.

SELECTED PRESENTATIONS

- **H. Kim**, "Fast Matrix Construction Algorithm from Pauli Polynomial" (Tensorized Pauli Composer). **Poster**, Quantum Threads 2024, Kyung Hee University, Seoul, July 2024. Related technical preprint: doi:10.5281/zenodo.14245728.
- **H. Kim**, "Trotter Circuit Optimization through Adiabatic Computer." **Oral presentation**, VQE Workshop, Korea University, 2023.

ADDITIONAL SOFTWARE PROJECTS

TorchPenny | Creator & Developer GitHub

- Built a framework integrating PennyLane circuits with PyTorch modules, enabling quantum layers to compose with standard `torch.nn.Module` models.
- Designed reusable circuit components with automatic trainable-parameter management and separate interfaces for input encoding, circuit structure, and measurement.

Booklet | Creator & Maintainer GitHub

- Created and maintain an open-source Python package for PDF imposition and book-signature generation, including reusable page-layout APIs, packaging, and documentation; 50+ GitHub stars.

SELECTED HONORS

- **IonQ Mentoring Program (2024):** one of six groups selected nationally; project support exceeding $3,000 for quantum-algorithm research.
- **Korean Physical Society Undergraduate Research Presentation Competition (2024):** 3rd Prize among 30 participating teams.

TECHNICAL SKILLS

Programming	Python, C, Rust, Wolfram Language; Python-C APIs; package and API design
Quantum	PennyLane, Qiskit; Hamiltonian simulation, Trotterization, block encoding, Pauli representations
Scientific computing	NumPy, mpmath, GSL, SageMath, PyTorch; numerical linear algebra; arbitrary-precision computing
Theory & methods	Quantum complexity, circuit-depth and sampling-complexity analysis, perturbation bounds, Krylov/Lanczos methods; Git/GitHub, LaTeX