2025 Winter Classic Invitational Student Cluster Competition ORNL Challenge: "Benchmarking a quantum linear systems algorithm"

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Logistics

- GitHub Repo:
  https://github.com/olcf/wciscc2025.git
- Project ID for accessing OLCF Odo and IQM machines:
  TRN037
- Timeline:
  - Competition period: 10-15 February 2025
  - Submission deadline: 15 February 2025, 5 pm Pacific
  - Mentor support: 10-14 February 2025, 9 am - 5 pm Eastern
  - Evaluation/scoring period: 17-21 February 2025
- IQM availability:
  - Two 1-hour slots per day are reserved on IQM Garnet for the challenge.
  - M (3 pm), T (10 am, 3 pm), W (10 am, 3 pm), Th (10 am, 3 pm), F (10 am, 3 pm) All times Eastern
  - Utilize these slots since usage is free during this time. Other times will need credits, which are limited.
- Need help? Reach out to us in the Slack channel. Note that mentor support will be during 9 am - 5 pm (Eastern) from 10-14 February 2025.

Challenge

- Goal: Perform parametric study of a quantum linear systems algorithm (QLSA) on simulators, emulators, and real devices.
- Objectives:
  1. Shots-based study
     - Objective: Convergence of the accuracy (fidelity) with the number of shots.
     - Try changing the shots parameter and see how the fidelity of the results changes.
     - Complete the following tasks to solve the tridiagonal Toeplitz matrix problem.
     - Run on simulator only.
     - Tasks:
     (a) Convergence plot of fidelity for solving matrix of size 2×2. Shot range from 100 to $1,000,000$. Report your deduction of the converged shot value. **(5 points)**

(b) Change in fidelity and error due to shots, uncertainty quantification (UQ), with increase in problem size (matrix size range from 2×2 to 32×32). Choose shot value following the convergence study from Task 1(a). Teams can select the UQ metric of their choice. Report number of times the circuit was run to obtain UQ. **(10 points)**

– See Fig. 1 for sample plots.

2. Backend evaluation
   - Objective: Compare the results for running the circuits on simulators, emulators, and real devices.
   - Complete the following tasks to solve the tridiagonal Toeplitz matrix problem.
   - Use IQM's emulator and real device.
   - Tasks:

   (a) Comparison of quasi-probability distribution of results for solving matrix of size 2×2. Use shot value based on Task 1(a). **(10 points)**

   (b) Comparison of fidelity and UQ for various backends (matrix size 2×2). Use guidance from Task 1(b). **(10 points)**

   - See Fig. 2 for a sample plot.
3. Solve the Hele–Shaw flow problem
   - Objective: Push the limits to tackle the Hele-Shaw flow problem.
   - Report results for both pressure and velocity. For velocity, report two results - (1) using ideal/analytical pressure solution; (2) using pressure solution from the HHL solver.
   - Plot pressure and velocity profiles.
   - Run on simulator only.
   - Tasks:

   (a) Report maximum fidelity achieved for problem size $nx = 3, ny = 3$. **Perform analysis based on procedures followed in previous tasks.** Points will be normalized between the top and lowest scoring team. **(min 1 point, max 15 points)**

   - See Fig. 3 for sample plots.

- Submission instructions
  - Create a submission directory for your team:
    `/gpfs/wolf2/olcf/trn037/proj-shared/[teamid]/submission`
  - Make the permission for this directory to user only:
    `chmod -R 700 /gpfs/wolf2/olcf/trn037/proj-shared/[teamid]/submission`
  - Submit a Python script for each task to show the plots or numerical results. Format for the script:
    `python team1_task1a.py`
  - All files should be Python scripts. Do not submit Jupyter notebooks.
  - The organizers will run your scripts (based on the above format, no additional input parameters) using the `qlsa-solver` conda env provided. The script should save the plots in the same directory.
  - Report: For each task, provide a concise description - these can include, but not limited to, the procedures you followed, any bottlenecks faced, how you overcame them, and choices you made for the various parameters/options in the task. Email the report as a single PDF document to gopalakrishm@ornl.gov by submission deadline. **NOTE:** The evaluation will also be based on this report.
- Additional details and tips
  - Use the conda envs already created to test your codes during the demo/challenge.
  - Instructions to install codes from scratch for offline trial is available in the GitHub repo.
  - Do not run on login node. Use interactive or batch modes.
  - Only use OLCF Open JupyterHub to try out sample visualization. This resource is limited. Try to use JupyterHub in your local machine.
  - Take advantage of simultaneous job steps to run multiple cases at the same time in a single job script.

Acknowledgements

This research used resources of the Oak Ridge Leadership Computing Facility at the Oak Ridge National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.

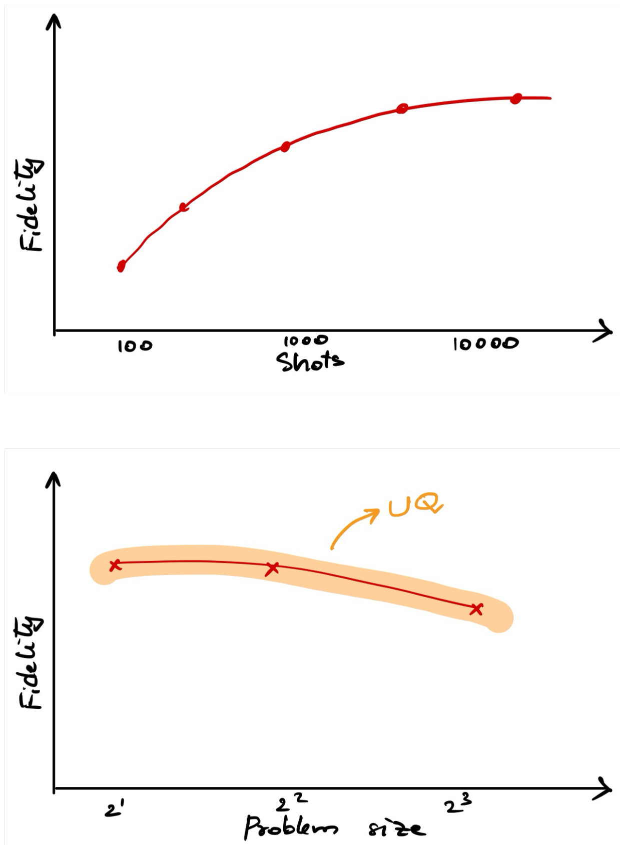

Figure 1: Sample depiction of (top) convergence of fidelity with shots and (bottom) change in fidelity with problem size - UQ is also indicated.

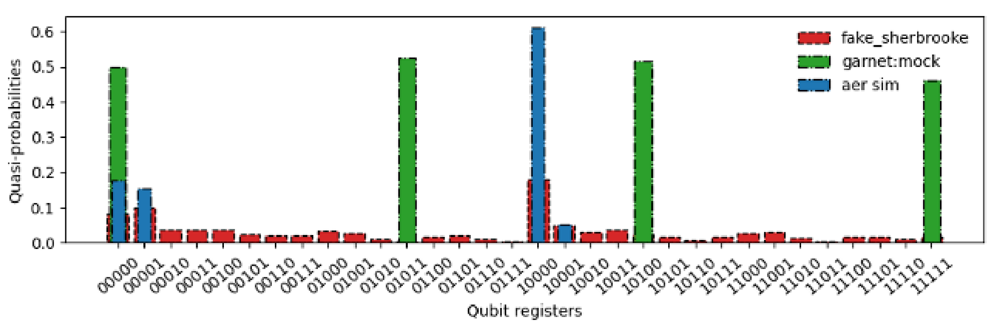

Figure 2: Comparing the quasi-probabilities of results from various backends.

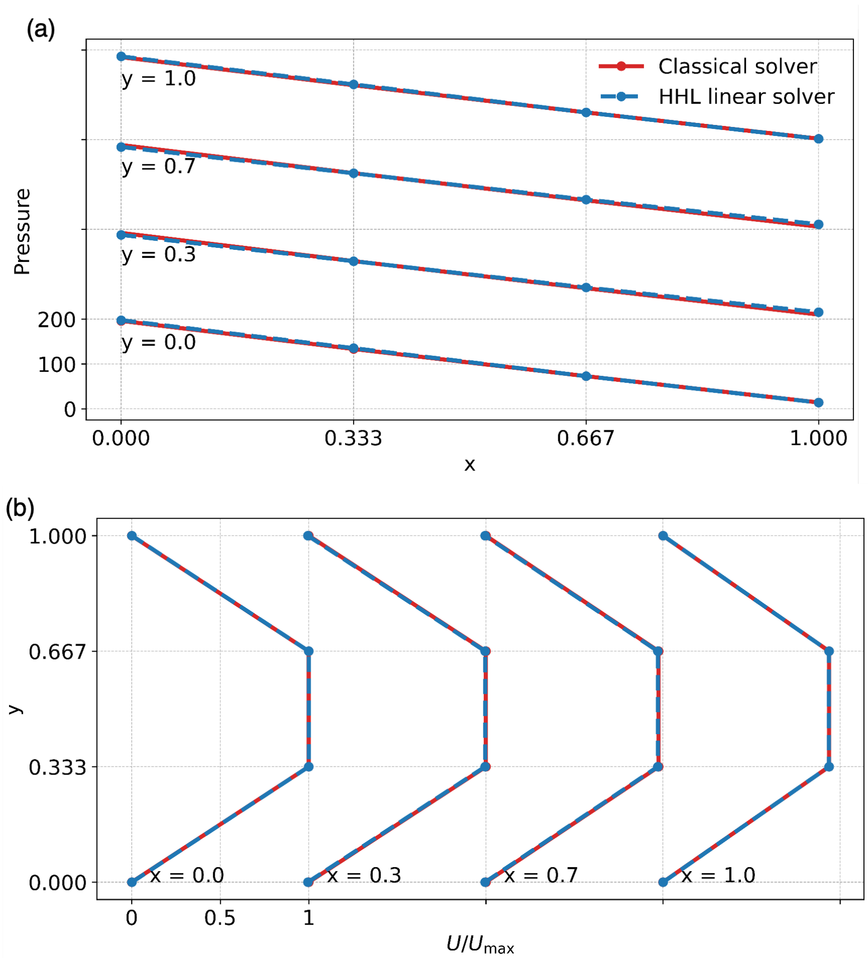

Figure 3: Sample depiction of (a) pressure and (b) velocity profile of the Hele-Shaw flow.