Womanium Quantum+AI 2024

Classiq <> Womanium

Development of Novel Quantum Algorithms

1. Project Overview:

The progress of quantum computers in the last few years has been immense, with better and better quantum computers being developed each year. Nowadays there are quantum computers with hundreds of qubits, that can compute quantum algorithms with circuit depth of up to a few thousands and still receive a significant signal. One of the key challenges of the quantum ecosystem is the **development of efficient and novel quantum algorithms that are useful and offer exponential advantage** over classical methods.

There are a few families of quantum algorithms that offer super-polynomial advantage:

- Hidden subgroup problems (discrete log, order finding etc.) with Shor's and HHL being concrete examples.
- Hamiltonian Simulation - with simulating classical coupled harmonic oscillators being a concrete example (surprisingly there is still no evidence for exponential quantum advantage for concrete quantum chemistry problems).
- Verifiability of quantumness - with Classically verifiable quantum advantage from a computational Bell Test being an example.

And some of the above algorithms can be captured in more general frameworks like QSVT and Quantum Walks. However, only very few of these algorithms have transformed from pure theoretical papers to concrete implementations that match today's capabilities of quantum software and hardware. Classiq's theme in the Womanium Global Quantum+AI 2024 program is to change this and thus to advance the quantum ecosystem forward.

The goal of this Womanium Quantum+AI Project is to implement, optimize, and assess any one of the algorithms above.

2. Project Duration:

- 4 weeks
- Teams start working on July 5, 2024
- Teams submit their project solutions on August 9, 2024

3. Team Guidelines:

- Team size - Maximum 3 participants per team.
- All team participants must be enrolled in Womanium Quantum+AI 2024.
- Everyone is eligible to participate in this project and win Womanium grants.
- Get selected for Womanium QSL fellowships with *Classiq.

4. Project Tasks/ Deliverables:

1) Participants need to implement, optimize, one of the following quantum algorithms using Classiq:
    a) Classically verifiable quantum advantage from a computational Bell Test.
    b) Exponential quantum speedup in simulating coupled classical oscillators.
    c) Evidence for the utility of quantum computing before fault tolerance.
2) The first step will be to implement a toy problem of the chosen algorithm. This should be a simple implementation (the simplest possible) that covers the:
    a) Encoding of the problem.
    b) The key algorithmic building blocks of the chosen paper (e.g. Hamiltonian simulation).
    c) The readout and post-processing.

    The implementation should be scalable, such that it is clear how to extend it for a more complicated scenario, and it should be checked and tested using a simulator.
3) The second step is to enlarge the problem for a more complicated scenario. In this step, the actual problems from the papers should be implemented (e.g. the actual Hamiltonian that is shown in the paper should be implemented). Resources estimation in terms of circuit depth, circuit width and number of 2-qubit gates should be made and compared across several hardwares.
4) The last step would be to optimize the solution for the most adequate hardware that was found in the second step.

Deliverables:

- Slides that summarize the work.
- The .qmod and .qprog files for each step.
- The Python Jupyter notebooks of each step (if applicable).

5. Quantum Hardware Credits / Platform:

- Preferred platform - Participants must use the Classiq platform, using which they can compile and optimize their solutions to any hardware/simulator as they wish.
- Hardware credits provided - Classiq will provide credits (up to $10,000) to run on real hardware for good solutions. This is approved on a case by case basis by Classiq.

6. Judging Criteria:

- The use of high-level functional design in the implementation:
  - The use of native statements of the Qmod language.
  - The use of synthesis configurations and optimization of the model.
- Successful implementation and submission of the project is necessary to pass the project, and earn the Womanium Quantum+AI Project Certificate.
- Criterias like the extent of which the implementation addresses the problem in the paper, the scale of the implementation, the quality of the implementation in terms of the resources required, and additional work such as error mitigation will be used to judge the projects.
- Completing all tasks makes you eligible to compete for QSL fellowships. Finalists for QSL fellowships will be decided on the basis of Highest cumulative scores from all tasks, Technical Merit, Novelty, Communication and Presentation Skills.

7. Resources:

- Classiq documentation
- The Classiq platform
- Classiq's Git library of many algorithms and applications
- Quantum Algorithms Zoo

* Participants currently residing in the following countries will not be eligible for QSL fellowships with Classiq: *Cuba, Syria, North Korea, Lebanon, Iran, Ukraine (Avtonomna Respublika, Krym, Luhanska oblast, Donetska oblast).*