Title: Architecting Hybrid Quantum-Classical Systems

Level: EECS 498/598

Credits: 4

Prerequisites: EECS 370 and/or permission of the instructor

Description:

Quantum computing is a disruptive technological paradigm with the potential to revolutionize computing and, therefore, the world. As quantum devices transform from laboratory curiosity to technical reality, we must unlock the full potential of quantum computing to achieve meaningful benefits on real-world applications with imperfect quantum technology. Researchers from classical computing backgrounds are critical to this endeavor as they are adept at bridging the information gap between different layers of the computing stack and have progressively accumulated expertise in building tightly constrained highly optimized classical systems.

This course will primarily focus on learning and research at the intersection of quantum and classical computing. The course will leverage several classical computing principles and use these as a foundation towards building a hybrid computing ecosystem for practical quantum advantage. The course will cover topics such as:

1. Introduction to quantum computing: theory to technology,
2. Hybrid quantum-classical algorithms,
3. Technology-aware circuit compilation for error mitigation,
4. Classical pre/post-processing for quantum executions,
5. Latency/bandwidth/power constrained design for error correction,
6. Scalable classical simulation to support quantum,
7. Multi-quantum-chip strategies and distributed computing,
8. Quantum cloud resource management,
9. Benchmarking and design space exploration,
10. Scientific computing and quantum intersections

The course will review fundamentals in these areas, discuss recent literature on these topics, identify challenges, and explore potential future research opportunities.

The course will assume some background in computer organization i.e., some minimal understanding of programming (e.g., Python / C++), compilers, computer architecture, computer hardware-software interface, digital logic, memory, etc. Students are requested to reach out to the instructor if they do not have the required background.

Material will be taught and discussed in the course for the first 75% of the classes. The final 25% of classes will be reserved for the project - students will have the opportunity to brainstorm ideas, resolve challenges, and discuss their progress.

Grading:
1. Paper presentation/lecture (10% of the overall grade): Every team, consisting of one to four students, is expected to lead up to one/two lectures. Each of these lectures will focus on discussing assigned papers on a particular topic. The presentation should cover both the material presented in the paper, as well as necessary background information and an overview of the related work.

2. Paper review (15% of the overall grade): Students are expected to study and analyze the papers assigned for each lecture and submit their reviews.

3. Class participation (5% of the overall grade): Students are expected to actively participate in the class.

3. Midterm (30% of the overall grade): Midterm will be held relatively late in the semester (at around the 75% mark), after the teaching material is complete.

4. Final project (40% of the overall grade):
a. Project proposal (5% of the overall grade): Each team is expected to submit a final project proposal. The project may range from the replication and extension of existing publication results to the investigation of new ideas related to hybrid quantum-classical systems. In each case, the team should clearly define their criteria for success. Teams are encouraged to pursue ambitious projects and coordinate with the instructor.
b. Project implementation (25% of the overall grade): Each team is expected to complete the final project and write a project report. Each implementation will be judged based on the success criteria described in the team's project proposal.
c. Project presentation (10% of the overall grade): Each team is expected to give a 20-minute in-class presentation about their final project.