King Fahd University of Petroleum and Minerals

College of Computer Science and Engineering
Computer Engineering Department

COE 530: Quantum Computer and Architecture

Term 222

Course Information

- Lectures: Sunday & Tuesday, 19:50-21:05 PM
- Location: Building 248-019 (Online)
- Office hours: UT 6:30-7:30 PM (or send me on Teams and I will try to accommodate your Qs online)
- Web page:
  - Blackboard page
  - https://faculty.kfupm.edu.sa/COE/mfelemban/COE530/212

Course Description

Review on Quantum Mechanics: Vector Space, Superposition, Bloch sphere; Classical bits, Quantum bits, and quantum states, Quantum circuits and micro-architecture, Programming quantum computers, Quantum protocols, Quantum machine learning, Applications of quantum computing.

Prerequisites

Graduate level

Course Objectives

The objective of this course is to

- Provide comprehensive understanding of how quantum computers work from computer science and engineering perspective
- Introduce the state-of-the-art quantum computing tools and technologies

Learning Outcomes

After taking this course, students will have the ability to

1. *Identify* the differences between conventional and quantum computing
2. *Explain* the circuits and architecture of quantum computers
3. *Identify potential applications suitable for quantum computers*
4. *Design and implement basic quantum computing applications*

Textbook

1. Thomas Wong. 2021. Introduction to Classical and Quantum Computing.
2. Yongshan Ding and Frederic T. Chong. Quantum Computer Systems: Research for Noisy Intermediate-Scale Quantum Computers. Synthesis Lectures on Computer Architecture 2020 15:2, 1-227

References

1. Johnson, Eric R., Nic Harrigan, and Mercedes Gimeno Segovia. Programming Quantum Computers: Essential Algorithms and Code Samples. O'Reilly Media, Incorporated, 2019.
2. Quantum Computation and Quantum Information: 10th Anniversary Edition by Michael A. Nielsen and Isaac L. Chuang Publisher: Cambridge University Press
3. N. David Mermin. 2007. Quantum Computer Science: An Introduction. Cambridge University Press, USA.
4. Heim, B., Soeken, M., Marshall, S. et al. Quantum programming languages. Nat Rev Phys 2, 709–722 (2020). https://doi.org/10.1038/s42254-020-00245-7
5. Noson S. Yanofsky and Mirco A. Mannucci. 2008. Quantum Computing for Computer Scientists (1st. ed.). Cambridge University Press, USA

Evaluation (Tentative)

Prog. assignments	20%	
Quizzes	15%	
Term project	20%	
Midterm Exam	20%	(TBD)
Final Exam	25%	(Date TBD by registrar)

List of Topics

The following schedule is tentative and subject to changes. More details will be announced in the class and course website/Blackboard.

1. Classical bits, digital gates, digital circuits, and computer architecture (2 weeks)
    a. Representation of classical bits in classical computers
    b. Digital gates (AND, OR, NAND, XOR NOT gate)
    c. Boolean functions and circuits
    d. Digital circuits (half-adders, full adders, ripple carry adder)
    e. Assembly language and compilers
    f. Computer Architecture
2. Quantum bits, quantum states, quantum circuits, and quantum architecture (4 weeks)
    a. Quantum gates
    b. Quantum circuits and architecture
    c. Quantum Instruction sets (QASM) and quantum compilers
    d. Quantum Programming Languages (Qiskit, Cirq, PyQuil, Q#)
    e. Quantum annealers
3. Quantum algorithms and protocols (5 weeks)
    a. Discrete Fourier Transform and Quantum Fourier Transform (without application)
    b. Simon's algorithm
    c. Quantum Phase estimation Algorithm
    d. Phase/Eigen value estimation
    e. Variational Quantum Algorithms (VQE, QAOA)
    f. Quantum Optimization Algorithms
4. Quantum machine learning (4 weeks)
    a. Quantum Support Vector Machine
    b. Quantum Neural Networks (QNNs)
    c. Quantum learning theory