Punjab University College of Information Technology
Allama Iqbal Campus (Old Campus), University of the Punjab, Lahore.

CS-526 – Quantum Computing

Course Description:

The course, CS-526–Quantum Computing, is particularly designed to introduce students with state-of-the-art aspects of quantum information, algorithms and error correction.

Goals and Objectives:

On the completion of this course students would be able to meet following objectives.

- Introduction to quantum information
- Learn Quantum Algorithms
- Quantum complexity theory
- Error detection and correction techniques

Course Contents

Linear algebra revision, complex number arithmetic revision, probability revision, qubits, single and multiple qubits gates, no-cloning theorem, partial measurement, superdense coding, entanglement, quantum teleportation, quantum Fourier transformation, Deutsch and Deutsch–Jozsa, Simon's algorithm, Grover's search algorithm, period finding algorithm, phase estimation algorithm, order finding algorithm, Shor's prime-factorization algorithm, Shor's discrete logarithm algorithm, error detection and correction techniques, quantum complexity theory.

Related Text / Reading Material:

1. YouTube Channel: https://www.youtube.com/playlist?list=PLxP0p--aBHmIe--9rczWe4AZmw03e2bz0
2. Nielsen, Michael A., and Isaac Chuang. "*Quantum computation and quantum information*." (2002): 558-559.
3. Faisal Aslam, "*Quantum Algorithms with Examples*", 2020
4. Childs, Andrew M. "*Lecture notes on quantum algorithms*." *Lecture notes at University of Maryland* (2017).
5. Mermin, N. David. "*Quantum computer science: an introduction*". Cambridge University Press, 2007.
6. Scott Aaronson Lecture notes
7. John Watrous's Lecture Notes

Scheme of Study

Week 1:

- Why everyone should read Quantum Computing?
- How Quantum Computers are different from classical computers?
- Common misconceptions about quantum computers.

Week 2:

- Introduction to superposition
- What are Qbits?
- Dirac notation

Week 3:

- Unitary and Hermitian matrices
- Properties of Unitary and Hermitian
- Why quantum gates must corresponds to Unitary matrices?
- Proof that only Unitary matrices preserve the norm of a vector.

Week 4:

- Key Quantum Gates and Universal Gates
    - Not Gate
    - Hadamard Gate
    - Rotation Gate
    - Phase Gate
    - Three Pauli Gates
    - Controlled-Not (CNOT) gate

Week 5:

- Computing tensor products
- Creating new gates using tensor product
- Creating quantum circuits
- Calculating output of a quantum circuit.
- Many example quantum circuits.

Week 6:

- Superdense Coding
  - Circuit diagram
  - Analysis
- Entanglement
  - Bell Basis
  - Proof of Entanglement

Week 7:

- Revision of basic probability
- Partial Measurement

Week 8:

- Quantum Teleportation
  - Circuit Diagram
  - Analysis
  - Implementation on IBM Quantum Computer

Week 9:

- Deutsch Algorithm
- Deutsch-Jozsa Algorithms
  - Their circuit diagram
  - Analysis
  - Implementation on IBM Quantum Computer

Week 10:

- The Simon's Algorithms
  - Circuit diagram
  - Analysis

- Implementation on IBM Quantum Computer

Week 11:

- Grover’s Algorithm
  - Its multiple examples
  - Circuit diagram
  - Implementation on IBM Quantum Computer

Week 12:

- Discreate Fourier transformation
- Quantum Fourier transformation
  - Implementation on IBM Quantum Computer
  - Circuit diagram

Week 13:

- Elitzur–Vaidman Bomb Detector
- Period finding algorithm
  - Implementation on IBM Quantum Computer
  - Circuit diagram

Week 14:

- More linear algebra revision
- Period Finding Algorithms
  - Implementation on IBM Quantum Computer
  - Circuit diagram

Week 15:

- Order finding Algorithms
- Shor's prime factorization
  - Implementation on IBM Quantum Computer
  - Circuit diagram

Week 16:

- Quantum Error correction
- Quantum Cryptography