Final Project: Building a Quantum Simulator

Quantum Computing (CMPS 4660/6660)

Overview

The goal of the final project is to design and implement a **quantum circuit simulator** that supports both **noiseless** and **noisy** simulation modes. Your simulator should execute quantum circuits efficiently, produce correct results, and allow users to specify hardware noise models.

Each submission must include:

1. **README** — with instructions on how to run the simulator;
2. **Source Code** — your implementation;
3. **Project Report** — a technical report describing algorithm design, correctness, and performance.

Functional Requirements

Your simulator must support:

- **Noiseless simulation:** exact simulation of quantum circuits without any noise;
- **Noisy simulation:** simulation under user-specified gate noise models.

The program should be easy to run, for example, if you implement it in Python:

```
python3 simulator.py -noiseless circuit.in
python3 simulator.py -noise circuit.in -error 0.01
```

For the noisy mode, users must be able to specify gate noise parameters: bit-flip probability.

Input Format Example

An example input file for the Deutsch–Jozsa algorithm is shown below:

```
// Deutsch-Jozsa for one of
// the balanced f : {0,1}^2 -> {0,1}^2
circuit: 3 qubits
X(2)
H(0)
H(1)
H(2)
// U_f
CNOT(0,2)
H(0)
H(1)
measure 0..1
```

README Requirements

Your README should clearly explain:

- Example input/output;
- Command-line usage examples;

Report Guidelines

Each report should contain:

- **Algorithm Design:** how quantum states are represented and evolved;
- **Performance Evaluation:** runtime and memory scaling with number of qubits and gates;
- **Noise Modeling (for noisy simulator):**
  - how hardware noise is modeled;
  - why this model reasonably approximates real hardware behavior.

Collaboration Policy

- **Graduate students:** must complete the project individually.
- **Undergraduate students:** may form teams of up to three members.

Evaluation and Competition

Grades will be based on:

- **Correctness:** verified by benchmark circuits;
- **Performance:** time cost;
- **Report quality:** clarity and depth of analysis.

Two competitions will be held:

1. **Noiseless Simulator Competition:** ranked purely by performance.
2. **Noisy Simulator Competition:** evaluated on both runtime and the soundness of the noise model.

Winners: One winner for each category will receive **+5% bonus credit** toward the final grade.

Grading Breakdown

Component	Weight
Correct Implementation (Benchmark)	40%
Report and Analysis	30%
Performance Evaluation	20%
Code Quality & Documentation	10%