Middle East Technical University | Department of Computer Engineering

CENG 487

Introduction to Quantum Computing

Fall 2023-2024

Assignment II

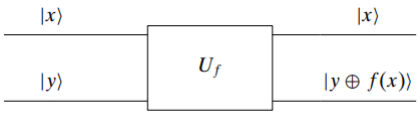
Due date: November 26, 23:59

Introduction

This assignment consists of two parts. In the first part, you are initially asked some theoretical questions related to the Deutsch's algorithm, then you need to implement two circuits for the Deutsch's algorithm. In the second part, you will implement three circuits for the Deutsch-Jozsa algorithm. The circuits will be implemented on IBM Quantum Computing. The necessary information regarding IBM Quantum Computing can be found in the first assignment. It will not be repeated here, please check that assignment for the clarification about the environment.

Part 1 - Deutsch's Algorithm (50 pts)

a) Show that whether the following gate U_f is invertible or not. *(10 pts)*



b) What is the result of the following term if $f(x) = \neg x$ ($\neg x$ refers to the negation of x); *(10 pts)*

$$U_f(H \otimes I)(|0\rangle \otimes |1\rangle)$$

c) Let $f(x) = x$ and $f : \{0,1\} \rightarrow \{0,1\}$. Is f constant or balanced? Provide a system to test this using Deutsch's algorithm with shots = 1024. *(15 pts)*

d) Let $f(x) = 1$ and $f : \{0,1\} \rightarrow \{0,1\}$. Is f constant or balanced? Provide a system to test this using Deutsch's algorithm with shots = 1024. *(15 pts)*

Part 2 - Deutsch-Jozsa Algorithm (50 pts)

a) Let $f(x) = x_0 \oplus x_1 \oplus x_2$ and $f : \{0,1\}^3 \to \{0,1\}$. Is f constant or balanced? Provide a system to test this using Deutsch-Jozsa algorithm with shots = 1024. *(15 pts)*

b) Let $f(x) = 1$ and $f : \{0,1\}^2 \to \{0,1\}$. Is f constant or balanced? Provide a system to test this using Deutsch-Jozsa algorithm with shots = 1024. *(15 pts)*

c) Let $f(x) = x_0 \oplus x_3 \oplus (x_1 \cdot x_2)$ and $f : \{0,1\}^4 \to \{0,1\}$. Is f constant or balanced? Provide a system to test this using Deutsch-Jozsa algorithm with shots = 1024. *(20 pts)*

Submission

- IMPORTANT! For the parts that require you to implement a system provide the screenshot of the system from the Quantum Composer (similar to what I did in HW1). At the end of the report provide the Qiskit codes of the systems as Appendix.
- You need to use real systems, just doing simulator runs will not accepted (although you are encouraged to use them).
- Submit a single **PDF** file named eXXXXXXX.pdf, where XXXXXXX is your student ID.
- Hand-written solutions will **not be accepted**.
- We have a late policy with penalty. The penalty is $5 * day^2$ where *day* is the amount of days submitted late. After three days, late submissions will not be accepted.
- The assignments are for individual work. We have zero tolerance policy for cheating. People involved in cheating will be punished according to the university regulations.
- You may ask your questions by sending a mail to "mduymus@ceng.metu.edu.tr".