Quantum Information Science

Special Subjects
Elective 2 credit

WATANABE, Ryuji

1. Course Description

This course provides an introduction to quantum computation. We will make a comparison between the quantum computers and classical computers from the viewpoint of the concept of computation. After reviewing the mathematics of tensor product of vector spaces and the physics on the rules of quantum mechanics, we will define the quantum gates which are the basic component of the quantum computation algorithm and formulate the mathematical model of quantum computer realized by the unitary transformation of the state vectors expressed by the tensor products of the quantum-bits. Finally we will overview the quantum computation algorithms of database search by L. K. Grover and of factorization by P. W. Shor.

The classes are based on self-learning such as reading the designated text books and answering the practice exercises prepared in each unit of the guidance book.

This subject is related to the clause 1 of the diploma policy of the Division of Informatics Science.

2. Course Objectives

Quantum computers which operate on the principles of quantum mechanics can fast solve the problems such as database search and factorization, though classical computers can't solve those within a reachable time. The aim of this course is to learn the outlines of the quantum computation algorithms of database search by L. K. Grover and of factorization by P. W. Shor and to understand the basic knowledge of mathematics for the quantum computation algorithms.

3. Grading Policy

The acceptance line is accuracy rate of 60% in the final exam.
The midterm papers(50%) and the final exam (50%) will be evaluated.

4. Textbook and Reference

Textbook

Yoshinori Uesaka "Mathematical Principles of Quantum Computation" Corona Publishing (2000) in Japanese. (ISBN 4-339-02376-0)

Reference

Shigeki Takeuchi "Quantum Computer" Kodansha (2005) in Japanese. (ISBN 4-06-257469-1)

Tetsuro Nishino "Quantum Computer and Quantum Cryptography" Iwanamishoten (2002) in Japanese. (ISBN 4-00-011159-0)

5. Requirements(Assignments)

Answering the practice exercises prepared in each unit of the guidance book is required as the midterm papers. The assignments should be prepared by handwriting.

Preparation of the linear algebra on an undergraduate level is also required. However, quantum mechanics, logical circuits, and number theory are not compulsory.

6. Note

Supplemental explanations on the related fields such as quantum mechanics, logical circuits and number theory, etc. are randomly given in the guidance book.

7. Schedule

[1] Concept of computation and classical computers.
[2] Characteristic of quantum computers : Schroedinger equation, Correspondence between quantum systems and logical data.
[3] Characteristic of quantum computers : Quantum parallelism and observation of the physical state.
[4] Linear algebra : 2 dimensional complex vector space.
[5] Linear algebra : Tensor product of vector spaces.
[6] Linear algebra : Tensor product of linear operators.
[7] Rules of quantum mechanics.
[8] Mathematical model of quantum computer.
[9] Simple quantum computer : Exclusive OR gate.
[10] Simple quantum computer : Logical AND gate.
[11] Simple quantum computer : Logical OR gate.
[12] Simple quantum computer : Copy gate, Branch gate, Exchange gate.
[13] Algorithm of database search : Grover's algorithm.
[14] Algorithm of factorization : Procedure of factorization, Discrete logarithm problem.
[15] Algorithm of factorization : Quantum Fourier transformation, Shor's algorithm.