SUBJECT OUTLINE

41076 Methods in Quantum Computing

Course area UTS: Information Technology

Delivery Spring 2023; City

Credit points 6cp

Requisite(s) ((41170 Introduction to Quantum Computing OR 43025 Introduction to Quantum Computing OR 68413 Quantum Physics) AND 37233 Linear Algebra)

Result type Grade and marks

Attendance: 3hpw

Subject coordinator

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Teaching staff

Dr Maria Kieferova

Subject description

Quantum computing is a disruptive new technology since quantum computers promise dramatic advantages over current computers. Recent rapid physical experimental progress has made it possible that large-scalable and functional quantum computers will be built within 10 years. This subject exposes and demystifies quantum computing using a step-by-step approach. It introduces systematically the basic principles of quantum computing, quantum algorithms and programming methodologies and techniques so that the students can develop software to realise the superpower of quantum computers.

Subject learning objectives (SLOs)

Upon successful completion of this subject students should be able to:

1. Explain the advantages of quantum computing over classical computing.
2. Evaluate the application of quantum computing technologies to known and unknown contexts
3. Analyse efficiency and complexity of quantum technologies

Course intended learning outcomes (CILOs)

This subject also contributes specifically to the development of the following Course Intended Learning Outcomes (CILOs):

- Technically Proficient: FEIT graduates apply abstraction, mathematics and discipline fundamentals, software, tools and techniques to evaluate, implement and operate systems. (D.1)

Program

Week/Session	Dates	Description
1	7 Aug	Lecture 1: Motivation and formalism of quantum computing Introduction to quantum computing Models of computation The formalism of logic and quantum circuits **Notes:** Additional problems to practice pre-requisites will be given (optional).

2	14 Aug	Lecture 2: Introduction to quantum mechanics Quantum states (pure and mixed) Quantum operations (unitaries and channels) Measurement **Notes:** Problem set 1 will be released this week.
3	21 Aug	Lecture 3: Quantum Information Quantum information theory Tomography Noisy quantum channels **Notes:** Solutions to practice problems will be released.
4	28 Aug	Lecture 4: Building quantum computers Divincenzo's criteria Quantum stack Physics behind quantum computers **Notes:** Problem set 1 due in class.
5	29 Aug	Lecture 5: Dealing with noise NISQ Fault-tolerance Error detection and correction **Notes:** Problem set 2 released. Opportunities for feedback will be provided after class
6	4 Sept	Lecture 6: Quantum error-correction Quantum error-correcting codes Topological codes Surface code
7	11 Sept	Lecture 7: Quantum Complexity Turing machines Selected classical complexity classes Quantum complexity classes Classical vs. quantum computation **Notes:** Assigment 2 is due in class.

9	18 Sept	Lecture 8: Quantum Algorithms 1 The complexity of an algorithm Oracles and query complexity Elementary quantum algorithms (Phase kickback tricks, Hadamard/SWAP test, Hadamard transform) **Notes:** Problem set 3 is released.
9	25 Sept	No class this week - STUVAC
10	2 Oct	Lecture 9: Quantum Algorithms 2 Quantum Fourier Transformation Phase estimation algorithm Order finding and Shor's algorithm Grover search **Notes:** Assesment 2 (Out of a Quantum Box) is due in class.
11	9 Oct	Lecture 10: Entanglement Transformation Introduction to entanglement Bell's inequalities and CHSH game Measure of entanglement **Notes:** Problem set 3 is due in class.
13	16 Oct	Lecture 11: Quantum Communication Quantum cryptography and quantum key distribution Quantum internet **Notes:** Feedback on Assesment 2 is due in class.
13	23 Oct	Wrap up and in-class presentations **Notes:** Group presentation in class. Reports due in Nov 3rd, 23:59.

Assessment

Assessment task 1: Quantum technology analysis

Intent: To practice and hone skills in analysis of quantum protocols

Objective(s): This assessment task addresses the following subject learning objectives (SLOs):

2 and 3

This assessment task contributes to the development of the following Course Intended Learning Outcomes (CILOs):

D.1

Type: Exercises

Groupwork: Individual

Weight: 45%

Task: There will be three assignments each involving mathematical analysis of quantum technologies. Each assignment will be staged across 3-week periods and will require analysis of 3-5 known quantum protocols or other techniques. Each assignment will lead to 15% of the overall grade.

Length: As required to show working and correct answer.

Due: 3.00pm Tuesday 22 August 2023
Assessment consists of 3 problem sets, see the program.
See also Further information.

Assessment task 2: Out of the (Quantum) Box Presentation

Intent: To articulate and critically assess the known and possible applications of quantum technologies.

Objective(s): This assessment task addresses the following subject learning objectives (SLOs):

1 and 2

This assessment task contributes to the development of the following Course Intended Learning Outcomes (CILOs):

D.1

Type: Presentation

Groupwork: Group, group and individually assessed

Weight: 30%

Task: Choose a topic in quantum computing from a list given by the coordinator (additional topics might be allowed if agreed by the coordinator). Research, using relevant scholarly and/or popular resources, and/or imagine the application a future quantum technology might bring us. Discuss how the technology might serve or change society/business/personal lives/economy/health, engineering, etc and discuss the challenges and limitations of the quantum approach. Prepare and record a 5-10-minute presentation that discusses the technology and its application. Upload your video to YouTube/Vimeo/Dropbox and share your link with the class. Exceptionally creative videos can earn bonus points. Provide feedback to at least 2 other videos within two weeks after the submission deadline.

Length: 10-15 minute video

Due: 3.00pm Tuesday 12 September 2023

Assessment task 3: Quantum Protocol Project

Intent: To critically analyse quantum computing protocols, their shortcoming and advantages compared to classical protocols

Objective(s): This assessment task addresses the following subject learning objectives (SLOs):

1 and 2

This assessment task contributes to the development of the following Course Intended Learning Outcomes (CILOs):

D.1

Type: Report

Groupwork: Individual

Weight: 25%

Task: This assessment includes a in-class presentation and a submitted written report.

Students will choose a protocol from a list given by the coordinator. They will need to use classical and quantum literature to determine how the protocol compares to its classical counterpart, what are its limitations and when and how could it be successfully deployed

Length: 1500-3000 words

Due: 11.59pm Friday 3 November 2023
final report due on Nov 3, presentation during the last class

Assessment feedback

Feedback on rewritten assignment 1 will be given 2-3 weeks after the marking is done.

Feedback on the video assignment 2 will be a summative grade with a marking sheet that shows the achievement degrees against the marking criteria, which will be provided 2-3 weeks after the due day.

Feedback on group presentation will be given in class after presentation is finished.

Minimum requirements

In order to pass the subject, a student must achieve an overall mark of 50% or more. There is no attendance or partcipation requirements in this subject.

Recommended texts

Michael Nielsen and Isaac Chuang, "Quantum Computation and Quantum Information," Cambridge University Press.

Phillip Kaye, Raymond Laflamme and Michele Mosca, "An Introduction to Quantum Computing", Oxford University Press

Other resources

Additional resources will be given for individual lectures

Graduate attribute development

For a full list of the faculty's graduate attributes refer to the FEIT Graduate Attributes webpage.

For the contribution of subjects taken in the Bachelor of Engineering (Honours) or Master of Professional Engineering

to the Engineers Australia Stage 1 Competencies, see the faculty's Graduate Attributes and the Engineers Australia Stage 1 Competencies webpage.

Assessment: faculty procedures and advice

Marking criteria

Marking criteria for each assessment task will be available on the Learning Management System: Canvas.

Extensions

When, due to extenuating circumstances, you are unable to submit or present an assessment task on time, please contact your subject coordinator before the assessment task is due to discuss an extension. Extensions may be granted up to a maximum of 5 days (120 hours). In all cases you should have extensions confirmed in writing.

Special consideration

If you believe your performance in an assessment item or exam has been adversely affected by circumstances beyond your control, such as a serious illness, loss or bereavement, hardship, trauma, or exceptional employment demands, you may be eligible to apply for Special Consideration.

Late penalty

For Graded subjects:

Work submitted late without an approved extension is subject to a late penalty of 10 per cent of the total available marks deducted per calendar day that the assessment is overdue (e.g. if an assignment is out of 40 marks, and is submitted (up to) 24 hours after the deadline without an extension, the student will have four marks deducted from their awarded mark). Work submitted after five calendar days is not accepted and a mark of zero is awarded.

For some assessment tasks a late penalty may not be appropriate – these are clearly indicated in the subject outline. Such assessments receive a mark of zero if not completed by/on the specified date. Examples include:

a. weekly online tests or laboratory work worth a small proportion of the subject mark, or
b. online quizzes where answers are released to students on completion, or
c. professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date, or
d. take-home papers that are assessed during a defined time period, or
e. pass/fail assessment tasks.

For Pass/Fail subjects:

Work submitted late without an approved extension will only be assessed at the subject coordinator's discretion. Students who do not submit assessment tasks by the due dates may be referred to the Responsible Academic Officer under Student Rule 3.8.2, and a fail result may be recorded for the subject.

Request a review of a result

If you believe an error may have been made in the calculation of your result in an assessment task or the final result for the subject, it is possible to request a review of a result with the Subject Coordinator within five (5) working days of the date of release of the result.

Academic liaison officer

Academic liaison officers (ALOs) are academic staff in each faculty who assist students experiencing difficulties in their studies due to: disability and/or an ongoing health condition; carer responsibilities (e.g. being a primary carer for small children or a family member with a disability); and pregnancy.

ALOs are responsible for approving adjustments to assessment arrangements for students in these categories. Students who require adjustments due to disability and/or an ongoing health condition are requested to discuss their situation with an accessibility consultant at the Accessibility Service before speaking to the relevant ALO.

Statement about assessment procedures and advice

This subject outline must be read in conjunction with the Coursework Assessments Policy and the Courswork Assessments Procedure.

Statement on copyright

Please remember that teaching materials and resources provided to you at UTS are protected by copyright. You are not permitted to re-use those for any purposes (including commercial purposes, in kind benefit or gain) without permission of the copyright owner. Breaching copyright in relation to teaching materials and resources could lead to a legal action being brought against you.

Statement on plagiarism

Plagiarism and academic integrity

At UTS, plagiarism is defined in Rule 16.2.1(4) as: 'taking and using someone else's ideas or manner of expressing them and passing them off as ... [their] own by failing to give appropriate acknowledgement of the source to seek to gain an advantage by unfair means'.

The definition infers that if a source is appropriately referenced, the student's work will meet the required academic standard. Plagiarism is a literary or an intellectual theft and is unacceptable both academically and professionally. It can take a number of forms including but not limited to:

- copying any section of text, no matter how brief, from a book, journal, article or other written source without duly acknowledging the source
- copying any map, diagram, table or figure without duly acknowledging the source
- paraphrasing or otherwise using the ideas of another author without duly acknowledging the source
- re-using sections of verbatim text without using quote marks to indicate the text was copied from the source (even if a reference is given).

Other breaches of academic integrity that constitute cheating include but are not limited to:

- submitting work that is not a student's own, copying from another student, recycling another student's work, recycling previously submitted work, and working with another student in the same cohort in a manner that exceeds the boundaries of legitimate cooperation
- purchasing an assignment from a website and submitting it as original work
- requesting or paying someone else to write original work, such as an assignment, essay or computer program, and submitting it as original work.

Students who condone plagiarism and other breaches of academic integrity by allowing their work to be copied are also subject to student misconduct Rules.

Where proven, plagiarism and other breaches of misconduct are penalised in accordance with UTS Student Rules Section 16 – Student misconduct and appeals.

Avoiding plagiarism is one of the main reasons why the Faculty of Engineering and IT is insistent on the thorough and appropriate referencing of all written work. Students may seek assistance regarding appropriate referencing through UTS: HELPS.

Work submitted electronically may be subject to similarity detection software. Student work must be submitted in a format able to be assessed by the software (e.g. doc, pdf (text files), rtf, html).

Further information about avoiding plagiarism at UTS is available.

Retention of student work

The University reserves the right to retain the original or one copy of any work executed and/or submitted by a student as part of the course including, but not limited to, drawings, models, designs, plans and specifications, essays, programs, reports and theses, for any of the purposes designated in Student Rule 3.9.2. Such retention is not to affect any copyright or other intellectual property right that may exist in the student's work. Copies of student work may be retained for a period of up to five years for course accreditation purposes. Students are advised to contact their subject coordinator if they do not consent to the University retaining a copy of their work.

Statement on UTS email account

Email from the University to a student will only be sent to the student's UTS email address. Email sent from a student to the University must be sent from the student's UTS email address. University staff will not respond to email from any other email accounts for currently enrolled students.