PHYS8909

Quantum Control

Session 2, Special circumstance 2020

Department of Physics and Astronomy

Contents

Notice

As part of Phase 3 of our return to campus plan, most units will now run tutorials, seminars and ot her small group learning activities on campus for the second half-year, while keeping an online ver sion available for those students unable to return or those who choose to continue their studies onli ne.

To check the availability of face-to-face and onlin e activities for your unit, please go to timetable vi ewer. To check detailed information on unit asses sments visit your unit's iLearn space or consult yo ur unit convenor.

General Information

Unit convenor and teaching staff Thomas Volz thomas.volz@mq.edu.au Daniel Burgarth daniel.burgarth@mq.edu.au	
Credit points 10	
Prerequisites Permission by special approval	
Corequisites	
Co-badged status PHYS7909	
Unit description The aim of quantum control is to drive a quantum system to a desired state or more generally evolution through pulse-shaping. The unit begins with introducing control theory as a subject from engineering and a tool for solving inverse problems. We will discuss linear control and bilinear control, both are important in the quantum case. We look at the Schrodinger equation as a bilinear control problem and aim to characterise what kind of states and operations can be reached in a given system. This leads us to an algebraic description of control, provided in the framework of Lie algebras. We will look at examples of how this works in practice in quantum computing. In such examples, one often encounters noise, and we will see how quantum control can help lowering noise, which leads us the control of open systems. A particular case of open system control is important in continuous variable quantum optics and known as the input-output formalism, which will bring us back to linear control. In the final part we introduce optimal control: to find the best way of controlling quantum system - shortest time, lowest energy, lowest noise. We look at examples from Nuclear Magnetic Resonance, from Ultrafast Laser Control, and from Quantum Computing. You will use the python library "QuTiP" to get experience with the beauty and the challenges of optimal control.	

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://www.mq.edu.au/study/calendar-of-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

ULO1: Distinguish linear, bilinear and general control systems and provide criteria for their controllability.

ULO2: Characterise the control properties of low-dimensional noiseless quantum systems.

ULO3: Explain basic concepts of the control of noisy systems and apply them to single qubit systems.

ULO4: Use the mathematical descriptions of input-output systems in quantum optics.

ULO5: Present physical arguments in quantum control through explanation of tutorial and assignment questions.

ULO6: Use the python library QuTiP to solve simple optimal control problems.

General Assessment Information

Individual oral examination via Zoom at the end of session. A demo oral exam will be provided on Zoom beforehand.

Computing lab held online (in the browser) via cocalc.com

Weekly to biweekly written assignments

Assessment Tasks

Name	Weighting	Hurdle	Due
Oral examination	40%	No	end of term
Project report	30%	No	weekly to biweekly
Problem sets	30%	No	second half of the session

Oral examination

Assessment Type [1]: Viva/oral examination
Indicative Time on Task [2]: 20 hours
Due: **end of term**
Weighting: **40%**

Oral examination in the Examination Period covering all course content

On successful completion you will be able to:

- Distinguish linear, bilinear and general control systems and provide criteria for their controllability.
- Characterise the control properties of low-dimensional noiseless quantum systems.
- Explain basic concepts of the control of noisy systems and apply them to single qubit systems.
- Use the mathematical descriptions of input-output systems in quantum optics.
- Present physical arguments in quantum control through explanation of tutorial and assignment questions.

Project report

Assessment Type [1]: Report
Indicative Time on Task [2]: 32 hours
Due: **weekly to biweekly**
Weighting: **30%**

Reports for numerical and computational projects

On successful completion you will be able to:

- Distinguish linear, bilinear and general control systems and provide criteria for their controllability.
- Characterise the control properties of low-dimensional noiseless quantum systems.
- Explain basic concepts of the control of noisy systems and apply them to single qubit systems.
- Use the mathematical descriptions of input-output systems in quantum optics.
- Use the python library QuTiP to solve simple optimal control problems.

Problem sets

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 30 hours
Due: **second half of the session**
Weighting: **30%**

A sequence of problem sets throughout the session.

On successful completion you will be able to:

- Distinguish linear, bilinear and general control systems and provide criteria for their controllability.
- Characterise the control properties of low-dimensional noiseless quantum systems.
- Explain basic concepts of the control of noisy systems and apply them to single qubit systems.
- Use the mathematical descriptions of input-output systems in quantum optics.

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[1] If you need help with your assignment, please contact:

- the academic teaching staff in your unit for guidance in understanding or completing this type of assessment
- the Writing Centre for academic skills support.

[2] Indicative time-on-task is an estimate of the time required for completion of the assessment task and is subject to individual variation

Delivery and Resources

Delivery in 2020 will be managed via iLearn, with lectures delivered by both pre-recorded lectures on YouTube, live lectures on Zoom, and live seminars and discussions via Zoom.

Unit Schedule

The aim of quantum control is to drive a quantum system to a desired state or more generally evolution through pulse-shaping. The unit begins with introducing control theory as a subject from engineering and a tool for solving inverse problems. We will discuss linear control and bilinear control, both are important in the quantum case. We then look at the Schrodinger equation as a bilinear control problem and aim to characterise what kind of states and operations can be reached in a given system. This leads us to an algebraic description of control, provided in the framework of Lie algebras. We will look at examples of how this works in practice in quantum computing. In such examples, one often encounters noise, and we will see how quantum control can help lowering noise, which leads us the control of open systems. A particular case of open system control is important in continuous variable quantum optics and known as the input-output formalism, which will bring us back to linear control. In the final part we introduce optimal control. The task here is to find the best way of controlling quantum system - shortest time, lowest energy, lowest noise. We look at examples from NV spins, cavity QED, and from Quantum Computing. You will use the python library "QuTiP" to get experience with the beauty and the challenges of optimal control.

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central (https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-centr al). Students should be aware of the following policies in particular with regard to Learning and Teaching:

- Academic Appeals Policy
- Academic Integrity Policy
- Academic Progression Policy
- Assessment Policy
- Fitness to Practice Procedure
- Grade Appeal Policy
- Complaint Management Procedure for Students and Members of the Public
- Special Consideration Policy *(**Note:** The Special Consideration Policy is effective from 4 December 2017 and replaces the Disruption to Studies Policy.)*

Students seeking more policy resources can visit the Student Policy Gateway (https://students.mq.edu.au/support/study/student-policy-gateway). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

If you would like to see all the policies relevant to Learning and Teaching visit Policy Central (https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central).

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/study/getting-started/student-conduct

Results

Results published on platform other than eStudent, (eg. iLearn, Coursera etc.) or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au or if you are a Global MBA student contact globalmba.support@mq.edu.au

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to help you improve your marks and take control of your study.

- Getting help with your assignment
- Workshops
- StudyWise
- Academic Integrity Module

The Library provides online and face to face support to help you find and use relevant information resources.

- Subject and Research Guides
- Ask a Librarian

Student Services and Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

Student Enquiries

For all student enquiries, visit Student Connect at ask.mq.edu.au

If you are a Global MBA student contact globalmba.support@mq.edu.au

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.