Teaching Statement

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Philosophy

Mechatronics (Robotics) is an inherently interdisciplinary field crossing mechanics, control, algorithms, and statistics. Without a principled approach, teaching across these topics can be daunting at best and confusing at worst. By teaching fundamentals and demonstrating theory with experiments, I impart the excitement and confidence that comes from being able to tackle engineering problems in a principled manner with practical relevance.

Approach

My approach is to start with fundamental theory and emphasize it with experimental analysis. To the extent that engineering is a practicing profession, my goal is to show that "science" is an avenue for "design and development." Enthusiasm for the field and interactive lectures are helpful, but not sufficient. I use a scholarly approach to course development, that is, I employ a similar basis for teaching as I would for research. By using prior-art, teaching theory (e.g., PPP model), and course analysis, I am able to to track and continually improve teaching materials, thus yielding improved learning outcomes. For example, in MTRX 1701 (Introduction to Mechatronics), a motor laboratory was designed in consideration of ABET's Fundamental Objectives of Engineering Laboratories and ASEE publications.

Modern engineering is too complex for a rote education or trial and error. As Tesla lamented "a little theory and calculation would have saved (Edison) ninety percent of his labor." As evidenced by my teaching experience, commendations, and publications[1], I seek to deliver leadership in robotics education as well as research. My goal in both course development and delivery is to use best practices and recent research results to impart a firm theoretical basis, so that students can understand and advance the art.

Course Development & Research

It is an exciting time to be an engineering academic. Not only is robotics coming into its own, but the tools of teaching are rapidly evolving. As the Khan Academy, edX, etc. ("MOOCs") demonstrate, online delivery can be a focused learning environment; yet, the format, and subsequent course structure, are still nascent. By being a non-linear dissemination platform, a student can pace and augment content in a custom manner. It is also highly parallel and "social," to the (surprising) extent that large classes are better! However, this presents a number of challenges for Engineering, chiefly assessment and laboratories. Towards this I am developing and researching:

1. *Platypus* – a statistical peer-assessment system for use in ELEC 3004 (Systems). It randomly shuffles answers (per question) from multiple students and presents a peer grading system with greater levels of anonymity and cross-checking. By engaging the class (on both sides of the assessment process) and providing feedback quickly, it supports "deliberate practice" and helps students master core skills. By being automated, it simplifies analytics and to help identify patterns and "common misunderstandings."
2. Collaborative online laboratory education system – in collaboration with Dr. Ryan at the University of Sydney, I am looking at how robotics can assist in online design/laboratory courses and vice versa. The goal is for creativity, intuition, trust, and bravery; these skills are built in groups, hence a look at the online gaming community for tools to help coordinate and orchestrate this.

In latter year courses, I adopt a research-oriented approach to teaching robotics and systems, thus giving an appreciation of the process of researching and apply results from the literature in a rapidly developing field. For example, in METR 3800 (Mechatronics Systems Project II) and METR 4202 (Robotics and Advanced Control), the curriculum is structured to focus on "algorithmic" fundamentals and frameworks first with the goal that students should be able to understand the digest of a major robotics conference (e.g., ICRA). In contrast to shorter labs, this allows students to collaboratively design, plan, and execute a practical system giving them valuable experience for completing their final-year thesis research.

Where possible, I integrate research and teaching. For example, in METR 4202, the class was team taught and had a Skype expert guest lectures, such as one on RRTs from Prof. LaValle (author of *Planning Algorithms*, a seminal textbook on the topic).

Program Leadership

In addition to course development, I also serve as plan director for the Mechatronics program. In this role, I seek to foster independent learning through a tiered structure that starts with fundamental classes and progresses to a more complex courses where design is critical to learning outcome. This is done based on engineering education research, which shows that challenging laboratory exercises develop technical skills, problem reduction skills, and research and inquiry skills if there is a foundation to master upon. This is also in keeping with the notion of "deliberate practice" in which mastery arrives through setting specific goals, obtaining immediate feedback, and concentrating on the technique as much as the outcome. Student feedback is sought and quickly incorporated throughout the program.

I have sought to expand support for student societies (e.g, UQ Robotics Club, RoboGals, and RoboCup Jr.). I am seeking additional grant and industry support for the Mechatronics teaching laboratories (one of which is co-sponsored by ABB). To aid with program structure more broadly, I have completed a comparative survey amongst Mechatronics programs at peer institutions. This has helped shape the Mechatronics program at UQ to include more advanced mechanics and programming courses.

Proposed Courses & Teaching Interests

In addition to supporting undergraduate courses, I would like to introduce the following courses:

Dynamics and Control (Design) Laboratory

This course is aimed at advanced seniors and will build on theoretical control and sensing concepts by having teams design, construct, and feedback control an experimental system, such as a double pendulum, *from scratch*. It will include sensors, actuators, circuits, and the physical plant modeling. It will start by reviewing classical (frequency) control design techniques and then teach the electronic elements needed for sensors and actuators design. Through laboratories and lectures, the course will introduce concepts in controllers, tuning, noise, saturation, sensor placement and linearity. Later parts of the course will be devoted to introducing state-space design and will emphasize industrial examples. Based on my experience with similar courses, this is popular with students pursing both industrial and research careers.

Algorithmic Foundations of Modern Robotics

Similar to the course of the same name that I managed and helped start at the ACFR, this graduate course provides an overview of the major topics in robotics research. The aim of the course is to bring new graduate students in robotics, who are from increasingly diverse fields, up to speed on the key concepts and algorithms in modern robotics with the goal that they can read and understand papers contained in a current RSS proceedings. Where possible, I would structure the course to be team-taught so as to provide a diverse a background and introduction.

Teaching Experience

My diverse experience with both large and small courses in the US and Australia, has received positive student feedback as acknowledged by a Teaching Commendation (University of Sydney AMME Department) and an Individual Teaching Award nomination (University of Western Australia). Courses taught include:

- Robotics and Advanced Control (UQ, METR 4202) (∼120 students) 2012
- Systems: Signals and Controls (UQ, ELEC 3004) (∼150 students) 2012, 2013
- Mechatronics Systems Project II (UQ, METR 1701) (∼60 students) 2011
- Introduction to Mechatronics (U. Sydney, MTRX 1701) (∼60 students) 2008, 2009, 2010, 2011
- Experimental Robotics (U. Sydney, MTRX 4700) – with Drs. Fitch and Williams (∼40 students) ... 2009, 2010, 2011
- Mechatronics Design (UWA, MCTX 3420) (31 students) 2008
- Mechanisms and Multibody Systems (UWA, MECH3422) – with Dr. K. Miller (180 students) 2008
- Stress, Strain, and Strength (Stanford, ME 80) – TA with A/Prof. B. Pruitt 2004, 2005
- Introduction to Sensors (Stanford, ME 220) – TA with Dr. T. Kenny 2002, 2004

Student Feedback

The University of Queensland - Robotics & Advanced Controls and Systems: Signals & Control

- EAIT (Faculty) Most Effective Teaching Nomination (2012)
- Course highlighted by university in program promotional materials
- Student Evaluation of Course and Teacher (SECaT): Course Overall: 4.81/5, Teacher Overall: 4.78/5 (*Highest in ITEE*, a department with $\approx$50 teaching staff)
- **Student Comments**: "Makes his lectures interesting (and is) passionate about what he teaches." and "one of the most approachable teachers I have come across"

University of Sydney - Introduction to Mechatronics and Experimental Robotics

- Dean's Award for Outstanding Teaching (2011)
- Dean's High Commendation (2011) for Introduction to Mechatronics
- AMME Teaching Committee Commendation (2010)
- Unit of Study Evaluation (USE): Overall: 3.96/5, Relevance: 4.43/5
- **Student Comments**: "The lectures and tutorial help me a lot in understanding this unit," "It encouraged me to continue further study," and "One of the nicest instructors at Sydney"

University of Western Australia - Mechatronics Design

- Individual Teaching Award nomination.
- Students' Unit Reflective Feedback (SURF): Overall: 3.4/4,
- Student Perceptions of Teaching (SPOT): Course: 4.11/5, Qualified: 4.47/5,
- **Student Comments**: "It's great having a lecturer who is enthusiastic and knows his stuff" and "I would like to thank you for your ever lasting enthusiasm consideration for students' needs. The unit would not have been as enjoyable or tolerable without your welcomed input."

Scholarly Teaching Development

As part of a principled approach to teaching and mentoring I have completed the following qualifications/programs:

- Graduate Certificate in Higher Education (U. Sydney, 2009)
- Research Higher Degree Supervision program
- Principles and Practices of University Teaching and Learning program

References

[1] S. P. N. Singh, R. Fitch, and S. Williams. "A Research-Driven Approach to Undergraduate Robotics Education". In: *Computers in Education Journal* 1.4 (2010), pp. 21–27.