Teaching robotics to the world

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Robotics is the next transformative technology

– it is the connection between ICT and useful action performed in the physical world
– it is emerging as the solution to profound problems facing modern society
– it is emerging as the next generation of high technology business:

“Robotics, $T of new business”

–– McKinsey report on disruptive technologies

http://www.mckinsey.com/insights/business_technology/disruptive_technologies
• To realise this revolution will require a new generation of people trained in robotics
<table>
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<th>SECTION 1: CAREER AND DEVELOPMENT PLANNING</th>
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Staff should articulate their longer-term career goals and plans for the next two to five years and consider any development implications associated with this planning.

These overall career and development goals should then provide the framework for planning over the next 12 month period (as articulated in SECTION 2: PLANNING PROPOSAL).

- Teach robotics and vision to the world: book, MOOC, QUT Robot Academy

- 10 years ago impossible
- Today quite possible
My journey
The beginnings

- I created and taught two units at UniMelb in 1982/83
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- I created and taught two units at UniMelb in 1982/83
- Spent 25 years working in applied research at CSIRO
- Completed my PhD part time
  - Open sourced some software tools I created along the way
The beginnings

• I created and taught two units at UniMelb in 1982/83
• Spent 25 years working in applied research at CSIRO
• Open sourced some software tools
• Took a year off to write a book about Robotics
A different type of book

Fig. 2.16

Robot end-effector coordinate system defines the pose in terms of an approach vector $\vec{a}$ and an orientation vector $\vec{e}$ from which $\vec{e}$ can be computed, $\vec{a}$, $\vec{d}$, and $\vec{v}$ vectors correspond to the $x$, $y$, and $z$ axes respectively of the end-effector coordinate frame. (courtesy of Kinova Robotics)

the gravitational acceleration vector (measured with accelerometers) which is by convention the $z$-axis and the heading direction (measured with an electronic compass) which is by convention the $x$-axis.

2.2.1.5 Rotation about an Arbitrary Vector

Two coordinate frames of arbitrary orientation are related by a single rotation about some axis in space. For the example rotation used earlier

$$ R = rpy2r(0.1, 0.2, 0.3); $$

we can determine such an angle and vector by

$$ [\theta, \vec{v}] = tr2angvec(R) $$

$\theta = 0.3655$

$\vec{v} = 
\begin{bmatrix} 0.1886 \\ 0.5834 \\ 0.7900 \end{bmatrix}$

where $\theta$ is the angle of rotation and $\vec{v}$ is the vector around which the rotation occurs.

This information is encoded in the eigenvalues and eigenvectors of $R$. Using the built-in MATLAB function

$$ [\vec{x}, \vec{e}] = eig(R) $$

$\vec{x} = 
\begin{bmatrix} -0.6944 + 0.0000i & -0.6944 + 0.0000i & 0.1886 + 0.0000i \\ 0.0792 + 0.5688i & 0.0792 - 0.5688i & 0.5834 + 0.0000i \\ 0.1073 - 0.4200i & 0.1073 + 0.4200i & 0.7900 + 0.0000i \end{bmatrix}$

$\vec{e} = 
\begin{bmatrix} 0.9339 + 0.3574i & 0.0000 + 0.0000i & 0.0000 + 0.0000i \\ 0.0000 + 0.0000i & 0.9339 - 0.3574i & 0.0000 + 0.0000i \\ 0.0000 + 0.0000i & 0.0000 + 0.0000i & 1.0000 + 0.0000i \end{bmatrix}$

the eigenvalues are returned on the diagonal of the matrix $\vec{e}$ and the corresponding eigenvectors are the corresponding columns of $\vec{x}$. From the definition of eigenvalues and eigenvectors we recall that

$$ 2\theta = \lambda \vec{v} $$

where $\vec{v}$ is the eigenvector corresponding to the eigenvalue $\lambda$. For the case $\lambda = 1$

$$ 2\theta = \vec{v} $$

which implies that the corresponding eigenvector $\vec{v}$ is unchanged by the rotation. There is only one such vector and that is the one about which the rotation occurs. In the example the third eigenvalue is equal to one, so the rotation axis is the third column of $\vec{x}$. 

2.2 · Working in Three Dimensions (3D)

Fig. 2.16.

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This is not unique. A rotation of $-\theta$ about the vector $-\vec{v}$ results in the same orientation.

Both matrices are complex, but some elements are real (zero imaginary part).

extra
detail

maths
code
figures
The beginnings

• I created and taught two units at UniMelb in 1982/83
• Spent 25 years working in applied research at CSIRO
• Open sourced some software tools
• Took a year off to write a book about Robotics
• Came to QUT in 2010 as a research capacity building professor
  – “it is considered that your role will be primarily research-oriented however will include some teaching…”
  – focus on grants, lab establishment, recruiting PhD students and postdocs
Teaching at QUT v1.0

• Created and taught two units at QUT
  – Introduction to Robotics: EGB339 from 2011
  – Advanced Robotics: EGB439 from 2012
• Very traditional format
Teaching robotics

• Engineering is about applying mathematics and science to create useful physical artefacts
• Robotics requires
  – knowledge of mathematical principles
  – expressed in software
  – running on a computer that controls a machine
• Overcoming “I’m bad at maths”
• There is a tension between doing/building and the theory to enable it, do we
  – start with theory and move to the practical?
  – start with the practical and backfill the theory?
...teaching robotics

- Do theory and practice in parallel
- Give students hardware, describe the end goal and let them play
  - creates an appetite for the theory
  - allows for variation in ability across the class
The bicycle incident

• 2 days before teaching started in semester 2, 2012
I uploaded my lecture videos to YouTube
Enter the MOOC

- 2013, let’s do a MOOC (or two)
- 2014-15, MOOC development
- 2015-16, MOOCs run
QUT MOOCs

2 x 6 week courses:
★ Introduction to Robotics
★ Robotic Vision

Each course:
• 2 one hour lectures/week
• Automatically graded assessment using MATLAB
• Project
• Open edX platform

2015: 30,000 students, 150 countries

One high achiever
I thank you professor for your efforts. The course was attractive and well explained. My grade was just a reflection of the course’s quality combined with a strong will to learn and a child’s love of robots (email, IR).

For some students it was a transformative life experience
Thank you Prof. Corke to provide opportunity for students in developing nations especially Papua New Guinea, where robotics is not taught as a Course in Computer Science and Engineering’ (IR forum post, 2015)

I’m pretty bad at maths but I understood most of the formulas....Compared to other free courses online this was by far the best. Instead of feeling frustrated because I haven’t understood the content of formulas thrown at me, after this course I actually feel I learned a lot and I have a good foundation to go deeper on this subject (RV, post-course survey, 2015)

I’m left with a lot of pride in the progress I made and all that I learnt. I left high school with the impression that I was no good at maths. In this course I really showed myself that I am capable of learning and applying maths (IR, post-course survey, 2015)
Teaching at QUT v2.0

• We used the MOOC modules for EGB339 in 2014
• Replaced a 2 hour lecture with
  – Out of class watching a set of MOOC modules
  – 1 hour interactive lectorial
    • questions via GoSoapBox, student driven agenda
    • no prepared slides, just some props and a document projector
    • real classroom engagement
• FaceBook group for discussion
  – easy to keep finger on the pulse of the class
More MOOCs

- 2013, let’s do a MOOC (or two)
- 2014-15, MOOC development
- 2015-16, MOOCs run

• 2016-, FutureLearn MOOCs

Problems with MOOCs

✘ Start & end dates will never suit everybody in the world
✘ The order of content is pre-ordained
✘ Not convenient to quickly gain knowledge about a small topic
✘ Platform cost and complexity
The post-MOOC era

• 2013, let’s do a MOOC (or two)
• 2014-15, MOOC development
• 2015-16, MOOCs run
• 2016-, FutureLearn MOOCs

• 2017-, Robot Academy
  – Post MOOC
    • “resources not courses”
    • “bite sized learning”
Robot Academy

- 200+ video lessons
  - each 5-10 minutes long
  - searchable by keywords
  - transcripts
  - formative questions
- 24 master classes (aka MOOC lecture)
  - each a sequence of video lessons
- Built using very standard technologies like YouTube, Bilibili and WordPress
Global reach is possible

- Online software tools,
  - Lifetime: 500k downloads
  - 1302 members of support group
- Book chapters
  - 750k downloads
- Online YouTube lectures (after 4 years)
  - Lifetime: 300k views, 5.1k subscribers
  - Last month: 6.8k views, 13 days of viewing
- Robot Academy (since May 2017)
  - Lifetime: 486k views, 67k users
  - Last month, 39k views, 7200 users, 54 days of viewing
  - 430 members of Facebook group
- TOTAL REACH 2M
AAUT 2017
Take home messages

• Think big
  – the world is full of hungry learners
  – online learning extends your reach and let’s you teach while you sleep!

• Enthusiasm and passion is gold
  – students sense it and respond to it

• Good design/aesthetics are important
  – it shows you care and made an effort (in classroom slides, book typesetting, MOOC production, etc.)

• Software is a means of teaching

• Instant gratification is important
In the classroom

• Mix it up in the classroom
  • Anecdotes, history, current events
  • Challenge them with questions
• Get them to imagine…
• Wander about, act things out
• Organization is really respected
• Chunk up the material, students can’t handle 2 hours straight
• Keep summarizing, recapping, flagging the next steps
• Explain where we are going collectively, and our goal
  • Explain why you do things
  • Structure your content
• Listen and encourage feedback
  • Adapt on the fly
  • Reflect your response to feedback back to the class
• We can help develop our junior colleagues through co-teaching

Thankyou for not standing behind a computer clicking through a powerpoint. Use of the whiteboard, and actual examples really livens things up — Pulse 2018