ME 729 – Robotics 2 - Analysis and Synthesis

Closing Remarks

Recall Motivation:

- ME 425/625 and 729 are the only robotics courses offered and coverage is dated
- ME 425 redesigned as intro to mechanisms, circuits, and programming for robotics
- ME 729 redesigned with lectures and labs to mathematically analyze and hands-on synthesize
- Resulting 2-course sequence instills core skills needed for robot engineering and research

Recall Implementation Challenges:

- Simulations (e.g. Matlab toolboxes): failure to appreciate real-world issues like communications
- Software (e.g. Matlab, OpenCV): accessibility (e.g. licensing); portability (e.g. Windows v. Mac)
- Hardware (e.g. robot kits): canned solutions, pricing and availability issues

Recall Approach:

Lego is robust and ubiquitous with a broad part range. Lego motors (backlash, footprint, and limited sensing) can be substituted with smart servos (e.g. XL-320 Dynamixel) and M2.5 fasteners. NXC, Code Blocks GNU C, and Scilab are free, do not require licensing, and thus easy to install. Serial ports, Bluetooth, and USB cameras reflect communications and sensing in real-world robotics.

Net effect: A universally accessible and sustainable approach to practice robot synthesis, enable life-long self-education, and motivate design, research and development

ME729 Synopsis

Lectures	Objectives	Outcomes
1-3	Foundations: communications, firmware programming	Serial ports; XL-320 programming
4-10	Analysis: DH, forward/inverse kinematics, trajectory planning	2-link planar manipulator labs reinforced theory.
Project 1 SCARA: Synthesize of 3-DOF robot based on analysis of DH, FK. And IK		
11-14	Analysis: Image and video processing	Thresholding, object properties (e.g. area, centroid), tracking (SSD)
Project 2 Visual-Servoing: Incorporate computer vision to servo robot		

ABET Relation to Program Objective

(0 = No content; 1 = some content; 2 = significant content)

Objective	Content	Explanation	Evidence*	Specific Examples
1. To deliver a comprehensive mechanical engineering curriculum which emphasizes both the **foundations** and breadth of the mechanical engineering profession	**2**	Advanced laboratory experience in robotics	Project reports and lab exercises	• Fundamental communications (Serial Port and Bluetooth) • Fundamental Firmware (XL-320 smart servo example) • Fundamental Computer Vision (image and tracking algorithms)
2. To provide an education that equips students with the tools necessary to become successful mechanical engineers based on their experience, strong **communication skills** and awareness for the need of continuous professional development.	**2**	Students are exposed to hardware and software tools, simulation and report writing.	Project reports, class handouts.	• Project 1 SCARA (written) • Project 2 Visual-servoing (written)
3. To provide an education that will allow mechanical engineering students to understand the **social, economic, environmental, political and ethical** importance of their future profession.	**1**	Digital concepts through hardware and software are essential in the design of robotic systems in automobiles, power plants and other vital areas of the economy.	Brief videos of robots and robot-based platforms for society e.g. rehabilitation and assistive robotics	• 12+ videos on robotics: ethics, rehabilitation robotics, social robotics, prosthetics • "Handbook of Robotics" future learning chapters
4. To provide mechanical engineering students with a thorough understanding of impact of mechanical engineers and the mechanical engineering profession in the development, implementation and creation of future technology	**2**	Development and innovation of robotics will be part of the future technology	Brief videos of robots and robot-based platforms for society e.g. driverless cars are introduced and discussed.	• 12+ videos on robotics: grasping, multi-robots, soft/compliant robots, human-robot interaction"Handbook of Robotics" future learning chapters

Relation to ABET Criteria 3 Learning Outcomes

(0 = No content; 1 = some content; 2 = significant content)

Criteria a – k	Content	Explanation	Evidence (Specific Examples)
a. An ability to apply knowledge of mathematics, science and engineering	2	Relevant physics, equations of motion, forward and inverse kinematics, trajectory planning	Analysis and synthesis of 2-link planar manipulator and Project 1 SCARA 3-dof robot
b. An ability to design and conduct experiments as well as to analyzed and interpret data	2	Students write software and interface mechanical and electrical hardware. They are also required to analyze and interpret the experimental data in the report.	Leverage Lego stud spacing to validate within 4 mm i.e. half-stud) end-effector locations
c. An ability to design a system, component or process to meet desired needs	2	Algorithms were implemented experimentally.	Projects 1 and 2; weekly homework (with YouTube demos)
d. An ability to function on multidisciplinary teams	0	Spring 2020: Only had 2 students; Remote-learning also limited opportunities for team work	Course has potential for team work
e. An ability to identify, formulate and solve engineering problems	2	The students are required to formulate and solve the forward and inverse kinematics based on theory and to verify their experimental results with expected theoretical results.	Weekly homework and Projects 1 and 2
f. An understanding of professional and ethical responsibility	1	This is emphasized as part of the design engineer's overall responsibility.	12+ videos throughout semester
g. An ability to communicate effectively	2	Oral and written presentations of the experimental procedure and results are required.	Project reports (written) and creating weekly homework with YouTube videos to communicate results
h. The broad education necessary to understand the impact of engineering solutions in a global or societal context	1	The impact of engineering design on the environment (pollution, greenhouse effect, etc.) and society are covered.	12+ videos throughout semester and discussion
i. A recognition of the need for and an ability to engage in lifelong learning	1	Ubiquity of Lego parts and license/cost-free software enables self-study and lifelong learning	Weekly lab Exercises (after each main concept was presented)
j. A knowledge of contemporary issues	1	Design of control systems is related to contemporary issues	Videos and discussion
k. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice	2	Students use modern engineering instrumentation and software	Lab exercises and project reports

So What? What one should have learned from ME 729?

DH notation, Forward, and Inverse Kinematics are the foundations; they are needed to analyze any robot. The 2-link planar manipulator is the simplest case study. Project 1 SCARA demonstrate their application to synthesize a 3-DOF robot. Higher DOF robots demand more matrix algebra (e.g. to compute inverse kinematics) but the process and procedures are the same as the case study.

Communications and Hardware Integration reflect real-world robotics; they are needed to almost any robot. The Lego NXT Brick (with one RS-485 port and Bluetooth) is a robust and compact all-in-one micro-controller. Other embedded microcontrollers have similar ports. The XL-320 Dynamixel is a smart servo. Many actuators also feature and demand firmware programming. The 2-link planar manipulator and Project 2 Visual-servoing demonstrates the applicability to synthesize a tracking robot. More sophisticated robots may incorporate more firmware and different micro-processors. But the process and procedures are the same.

Net effect: The hardware, software, their integration and algorithms reflect any robot system. With these core skills, one can design and synthesize even sophisticated high-DOF robots

Next Steps

Finals Week (next week): All content (including Trajectory Planning) after Mid-term

- Part 1: 90-min closed-book Theory
- Part 2: 60-min open-book Practical
- Return tackle box and contents: e.g. NXT Brick, XL-320 motors, cables, RS485
- Return camera tower baggie and white 32x32 baseplate

It's been a pleasure! Hope you enjoyed the experience!