EECS C106B / 206B Robotic Manipulation and Interaction **Spring 2020**

Lecture 1: Logistics and Review of Rigid Body Motion

Scribes: Suren Gunturu, Zoey Zhu

1.1 Goals

Prepare to do research in future

- Primary Areas: nonlinear control, path planning, mobile robotics, grasping, soft robotics
- Secondary Areas: legged robotics, active safety, HRI
- Not Covered: learning, estimation, SLAM, vision, mechatronics

General Research Skills: reading papers (a lot), presenting work (at least three), and writing reports (for all four projects)

1.2 Logistics

Prerequisites

- 106A
- EE128
- Lin Alg
- Python and MatLab
- Curiosity
- Interest in experimental work

Staff emails on course website
Piazza for fastest response
Lectures: T/Th 3:30-5 pm
No exams :D
HWs are biweekly
Five slip days, max two for one hw
Must scribe at least one lecture
Paper presentation: one in lab (same as one hw), slide or word based, twenty minutes
Projects: four total, 40-60 hours, groups of three, at least one who took 106A and one with controls experience
Can reserve robot three hours at a time and can only make new reservation when current expires else five percent deduction from project grade
Project due dates on website

Proj 1: trajectory tracking with control on baxter/sawyer
Proj 2: path planning with turtlebots
Proj 3: grasping with baxter/sawyer
Proj 4: soft robotics
Final Proj:

- proposal due 3/20 and presentations will be on friday of RRR week
- should be research projects applying multiple parts of the course material including some sensingm planning, and actuation

Graduate students have more expectations that undergrads can do for extra credit
Disc

- W 2:00pm-3:00pm 237 Cory, Valmik and Amay
- W 4:00pm-5:00pm 293 Cory, Valmik and Amay

OH

- Prof. Bajcsy: Weds 11-12, Thursday 1-2 (SDH 719)
- Prof. Sastry: Tuesday 1:15-2:30 (Cory 333B)
- Tiffany: Tuesday 11-12 (Cory 111)
- Amay: Monday 4-5 (Cory 111)
- Jun: Monday 5-6 (Cory 111)
- Valmik: Tuesday 12-1, Wednesday 5-6 (Cory 111)

Labs

- Thursday 5-8pm Cory 111, Tiffany
- Friday 11am-2pm Cory 111, Amay
- Friday 2-5pm Cory 111, Jun

Should be 1.5-2 hours most days, rest will be OH

1.3 Announcements

- Look at website
- Join Piazza and Gradescope
- Disc 1 tomorrow
- Lab 0 in lab sec this week
- HW 1 assigned tomorrow
- Project 1a released this week and will be discussed during lab section

1.4 Expectations

- Emphasis on collaboration and exploration
- Ask a lot of questions
- It's okay to be confused
- Expect to work hard

1.5 Rotational Matrices

will rotate any vector q about some axis w by an angle

represented as linear transformations

R:$R^3 \to R^3$

$q_A = R_{AB} q_B$

1.6 Linear Transformations

$T_{AA} : A \to A$

Left Multiplication: Change output frame $R_{BA}T_{AA} : A \to B$

Right Multiplication: Change input frame $T_{AA}R_{BA} : B \to A$

Change both input and output frames: $R_{BA}T_{AA}R_{BA}^{-1} : B \to B$

1.7 Groups

Rotations as a Group

> SO(n) are a group of special orthogonal matrices under matrix multiplication which can represent any rotation

Properties of Rotation Matrices:

> $R^{-1} = R^T$
>
> det(R) = +1

Properties of Groups:

> $Closure : \exists P, Q \in SO(n) \to PQ \in SO(n)$
>
> $Associativity : \exists A, B, C \in SO(n)(AB)C = A(BC)$
>
> $Identity : \exists I \in SO(n) s.t. AI = IA = A \forall A \in SO(n)$
>
> $Inverse : \forall A \in SO(n) \exists A^{-1} \in SO(n) s.t. AA^{-1} = I$

1.8 Lie Group

Rotations as a Lie Group

SO(n) is a continuous, smooth group which means that it has a tangent space

SO(n) at any point can define a tangent or derivative space

1.9 Lie Algebra

$so(n) = S \in R^{nxn} : S^T = -S$

example: so(2) and so(3)

1.10 Exponential Map

elements in lie algebra are essentially velocities moving at some velocity $\hat{w}$ for a time T to find any element in the group

$\dot{R}(t) = \hat{w}R(t)$

From t = 0 to T:

$e^{\hat{w}T}R(0) = e^{\hat{w}T}$

1.11 Practice Problem

SO(2)'s lie group is a circle while a line tangent to the circle would be its lie algebra or so(2)

1.12 More Rotations

Other Parameterizations of Rotations:

Using Euler angles: $R = R_x R_y R_z$

Axis Angle same as exponential

Unit Quaternions:

also a Lie Group

rotations correspond to 2 quarternions

computationally efficient

1.13 Velocities

Rotational Velocities

When we take the derivative of a rotation, we get a tangent plane of R at its current value, not so(n)

$q_a = R_{ab} q_b$

$\frac{d}{dt} q_a = \dot{R} q_b$

$\dot{R} : q_b \to \dot{q_a}$

1.14 Use Lie Groups for Rotational Velocities

Represent Rotational Velocities with SO(n)

body velocity:

$\hat{w}^b_{AB} = R^{-1}_{AB} \dot{R}_{AB}$

$= R_{BA} \dot{R}_{AB}$

$= \dot{R}_{BB}$

spatial velocity

$\hat{w}^b_{AB} = \dot{R}_{AB} R^{-1}_{AB}$

$= \dot{R}_{AB} R_{BA}$

$= \dot{R}_{AA}$