SCE 594: Special Topics in Intelligent Automation & Robotics

Lecture 1: Course Introduction & Set theory basics

جامعة الملك فهد للبترول والمعادن
King Fahd University of Petroleum & Minerals

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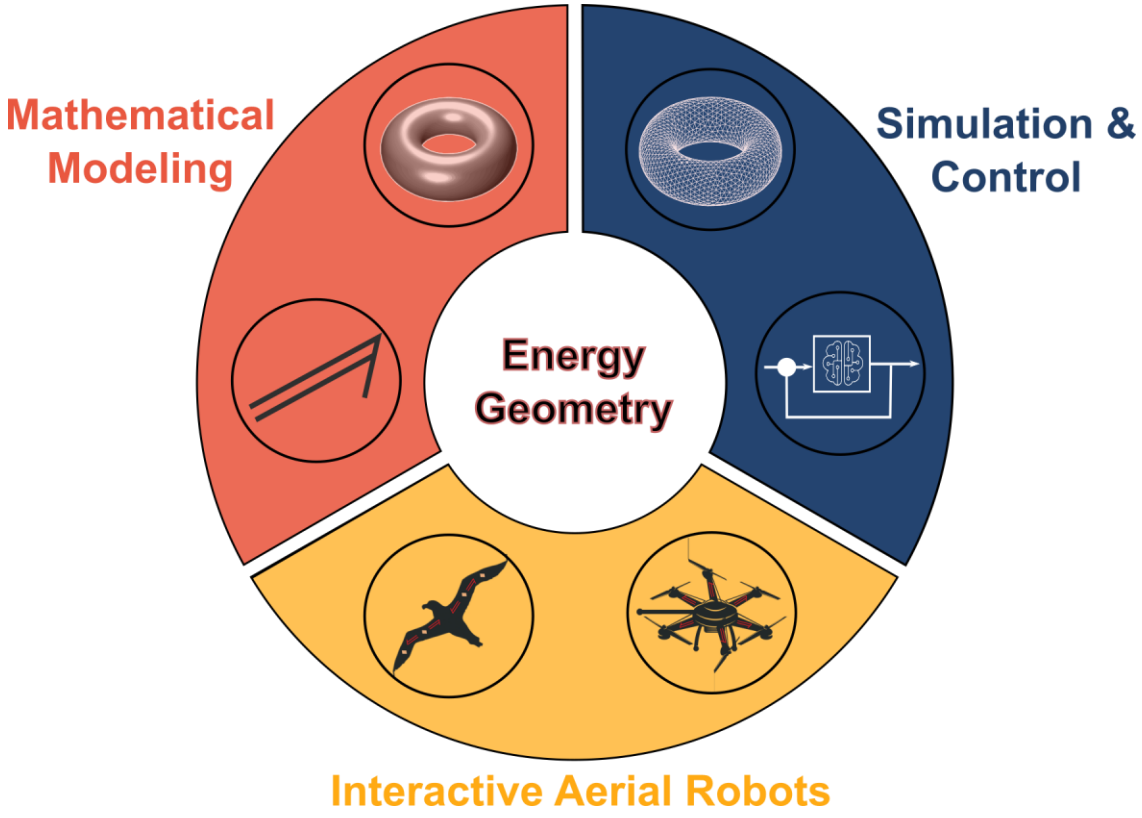
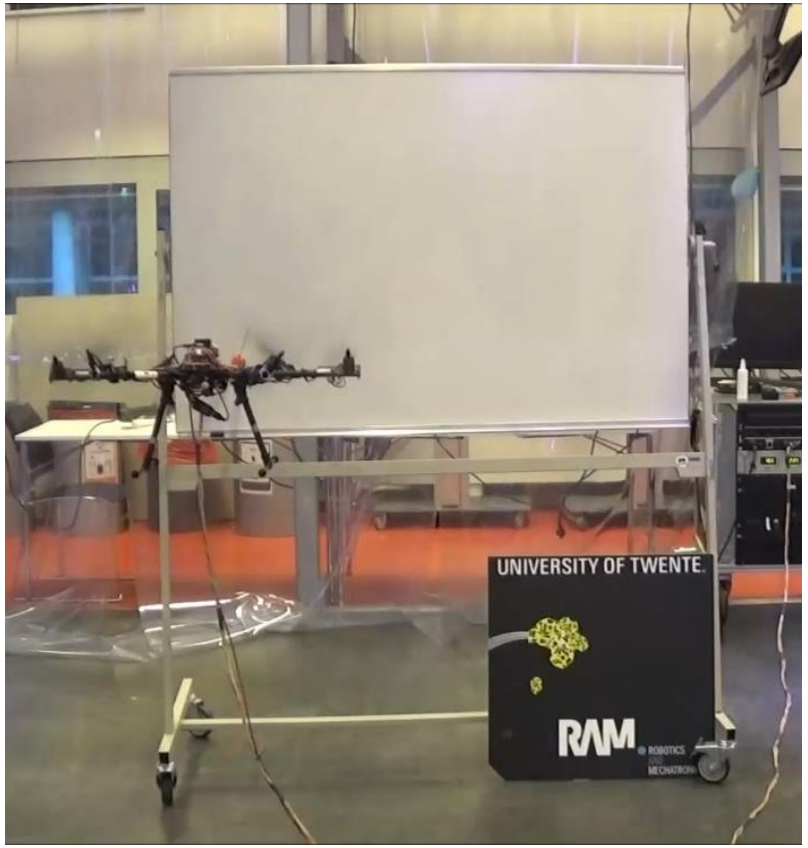
About Me

- 2013 - BSc - Mechatronics Eng. GUC
- 2015 - MSc - Mechatronics Eng. GUC
- 2013-2016 – Teaching Assistant at GUC
- 2021 PhD - RAM, UTwente
- 2021-2024 - Postdoc RAM, Utwente
- Now – Assistant Prof. KFUPM

My Research





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SCE 594 Course

Special Topics in Intelligent Automation & Robotics

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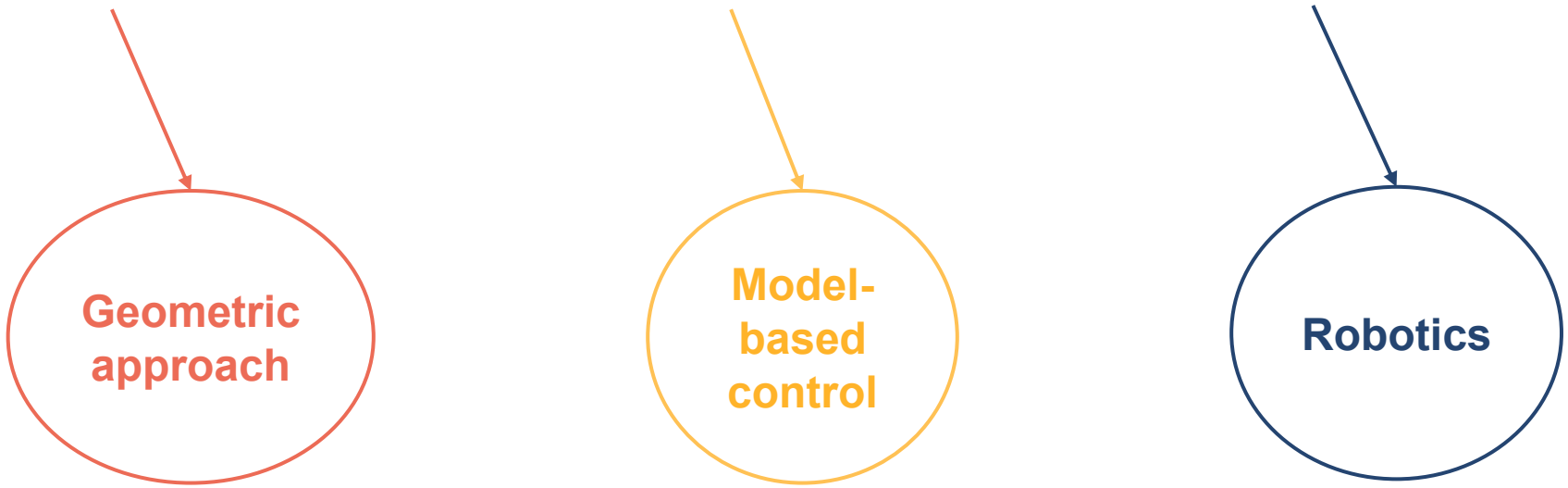
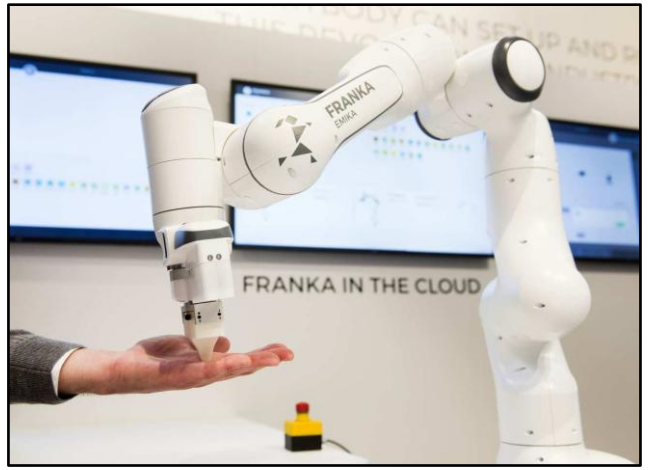
Geometric Modeling and Control of Robotic Systems



Robotic Systems

- Multi-rotor aerial vehicles
- Fixed-based manipulators



Why Geometric approach ?

- Geometric modeling and control uses tools from Differential Geometry.
- Differential geometry is a branch of mathematics focusing on non-Euclidean spaces & coordinate-invariance.
- Majority of Engineering education focuses on coordinate-based Euclidean geometry.

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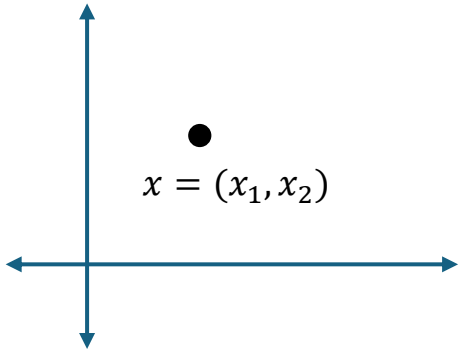
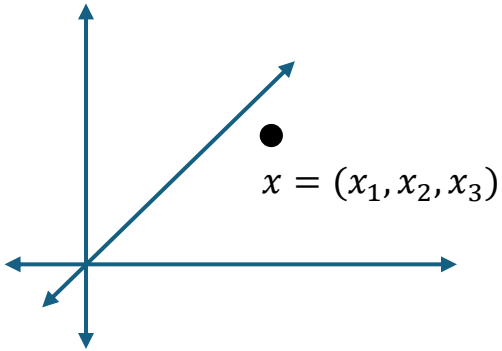
- Euclidean space $\mathbb{R}^n$

Line $\mathbb{R}^1 = \mathbb{R}$



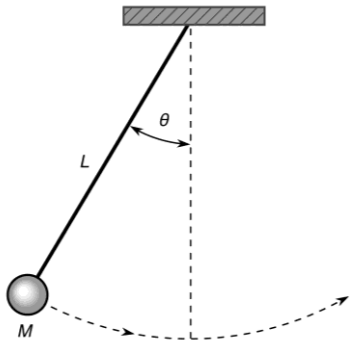
Plane $\mathbb{R}^2 = \mathbb{R} \times \mathbb{R}$

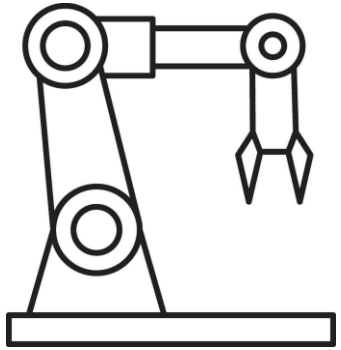


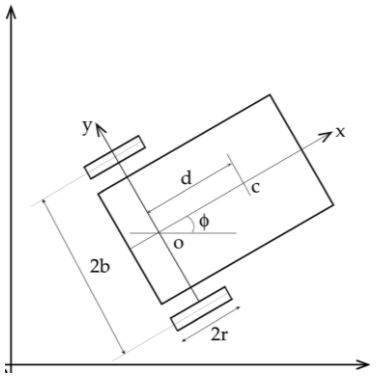
Plane $\mathbb{R}^3 = \mathbb{R} \times \mathbb{R} \times \mathbb{R}$

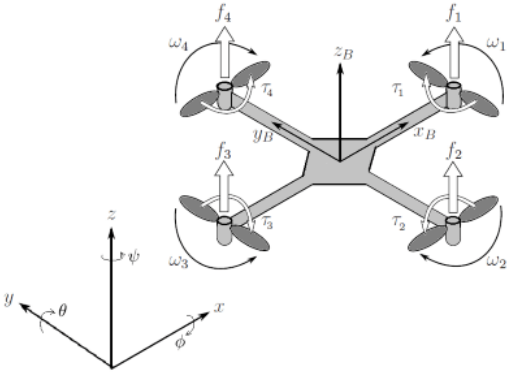
Why Geometric approach ?

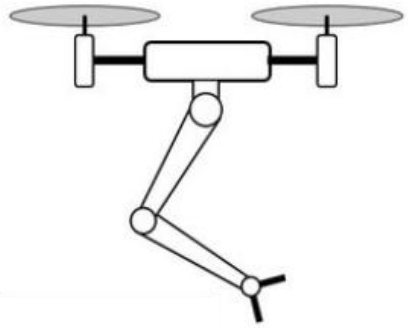
- Configuration space $\mathbb{Q}$ of (most) mechanical systems is not $\mathbb{R}^n$
  - Pendulum $\mathbb{Q} = S^1$
  - n-degree-of-freedom manipulator $\mathbb{Q} = T^n$
  - Planar mobile robot $\mathbb{Q} = SE(2)$
  - Multirotor aerial vehicle $\mathbb{Q} = SE(3)$
  - Aerial manipulator $\mathbb{Q} = SE(3) \times T^n$





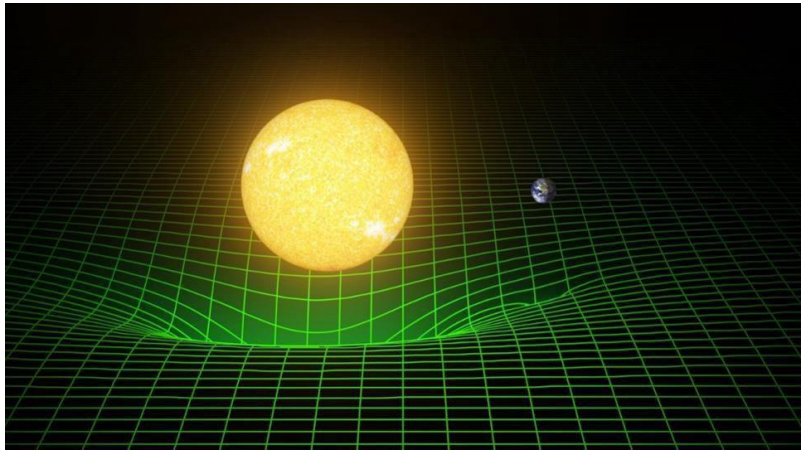






Why Geometric approach ?

- Differential Geometry is fundamental in modern Theoretical Physics
- The universe itself is not $\mathbb{R}^n$
  - Earth surface S^2
  - Spacetime (not space $\mathbb{R}^3$ + time $\mathbb{R}^1$)



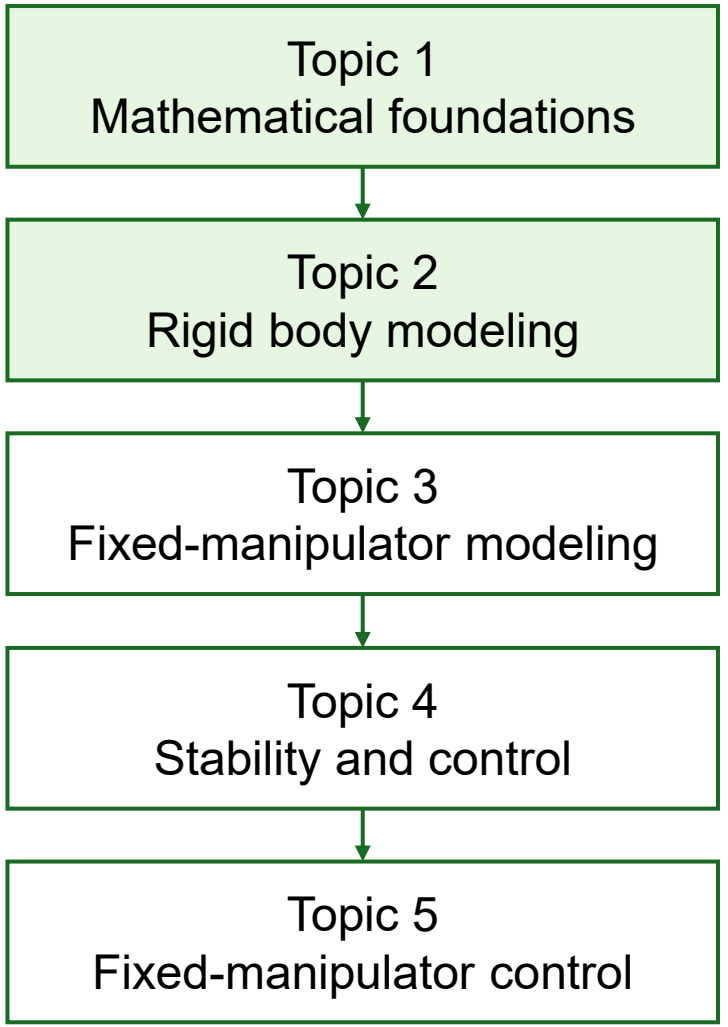
Outline

- Course Focus
- Why Geometric approach
- Course Logistics
- Topic 1: Mathematical foundations

Course Topics

1. Mathematical foundations
   - Set theory
   - Abstract linear algebra
   - Group theory
   - Manifold theory
   - Lie group theory

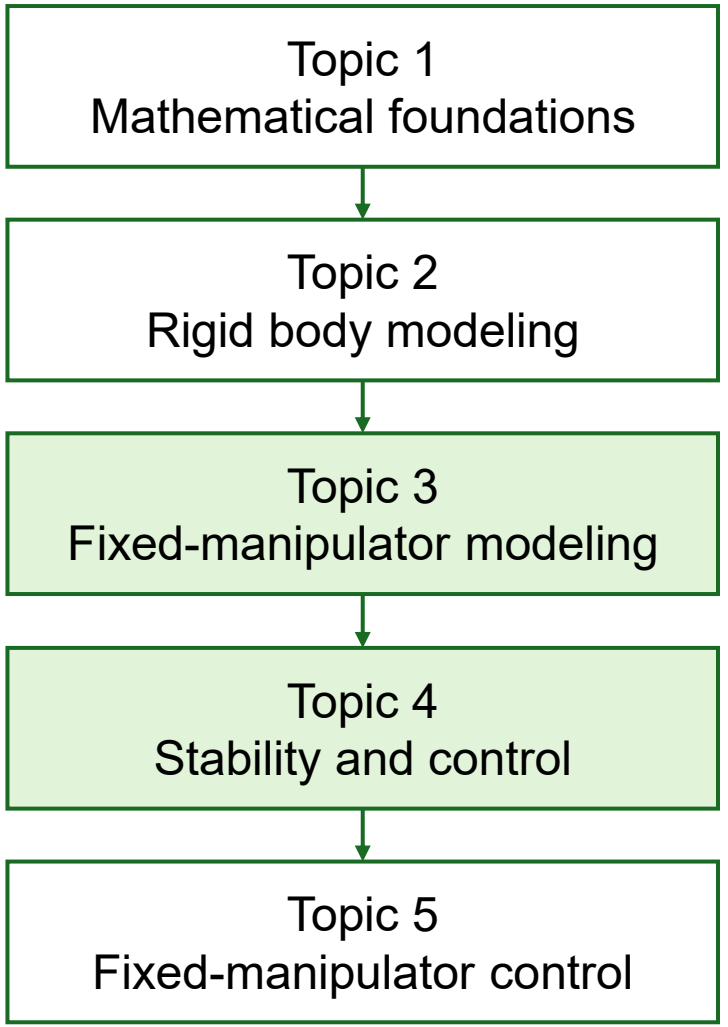
2. Rigid body modeling
   - Configuration space
   - Kinematics
   - Dynamics



Course Topics

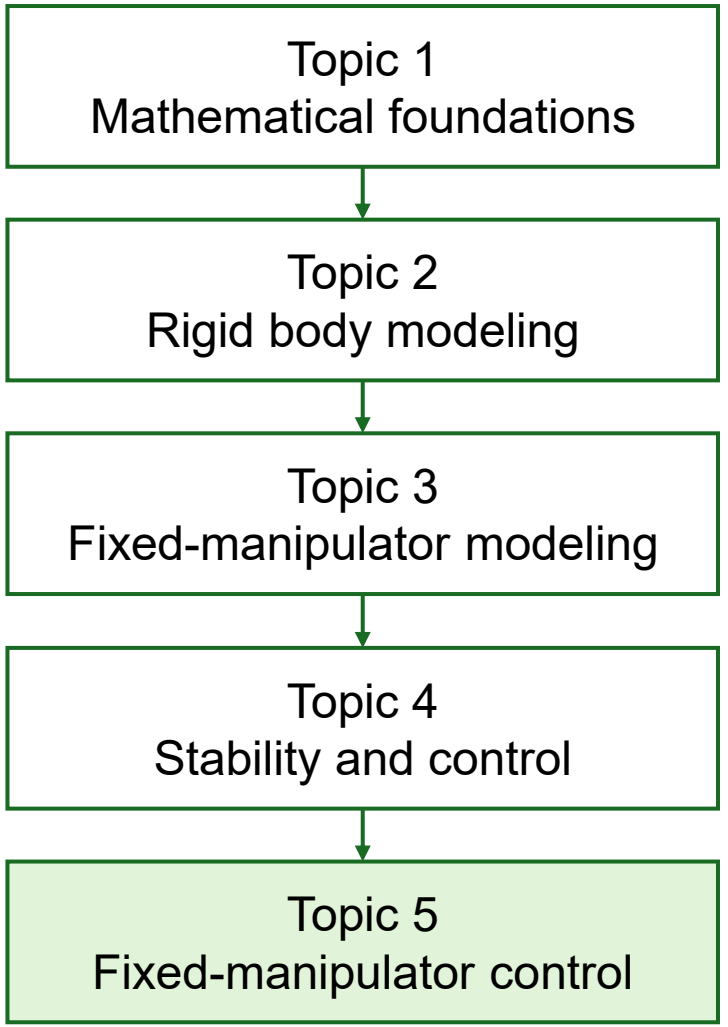
3. Fixed-base manipulator modeling
   - Joints
   - Forward Kinematics
   - Dynamics
   - Actuation, gearing, friction, constraints

4. Stability and control of mechanical systems
   - Lyapunov stability
   - Geometric PD control
   - Multi-rotor aerial vehicles



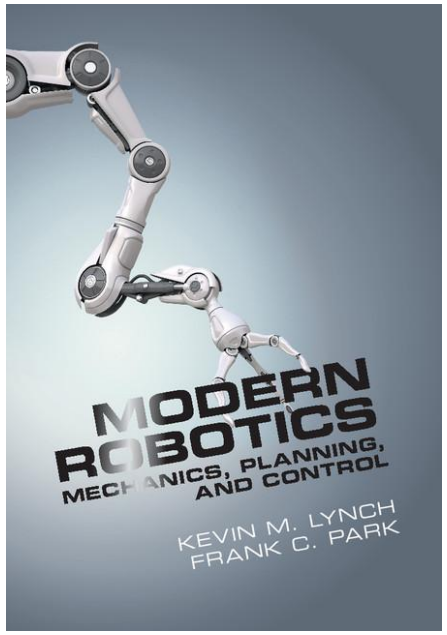
Course Topics

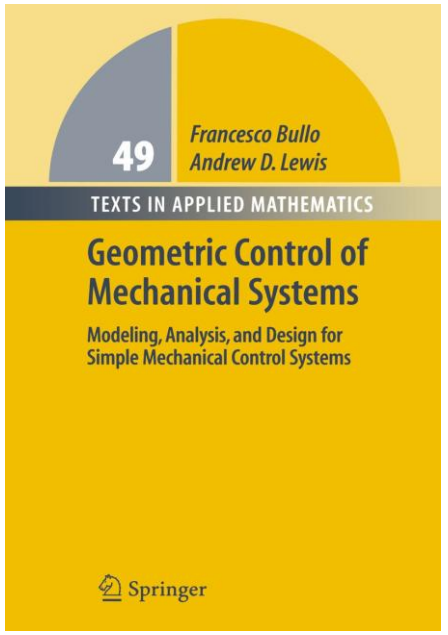
5. Fixed-base manipulator control
   - Motion control
   - Interaction control



Course Theme

- SCE594 is an intensive graduate-level course
- SCE594 is an “advanced” applied mathematics course
  - Pre-requisite is familiarity with linear algebra
- SCE594 includes programming assignments
  - Pre-requisite is familiarity with MATLAB



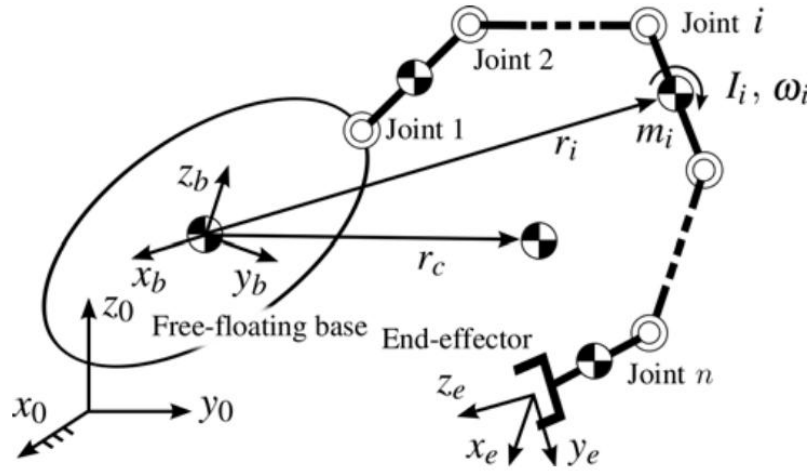


Course Assessment

- Assignments 25 %
- Quiz 5 %
- Midterm Exam 20 %
- Group Project 25 %
- Final Exam 25 %

Group Project:

- Model-based control
- Motion & Interaction control
- Complex robotic system
- Simulation



Study materials

- Video recordings
  - Posted on Youtube (Unlisted)
  - Will be made public at the end of course
  - You have the ‘right to be forgotten’
- Selected reading material from textbooks
  - Posted on Blackboard on weekly basis
- Lecture slides
  - Posted on Blackboard on weekly basis
- Your personal notes !!
- Lecture notes – Work in progress


ARE YOU
READY?


FASTEN SEAT BELTS

Outline

- Course Focus
- Why Geometric approach
- Course Logistics
- Topic 1: Mathematical foundations
  - Structure hierarchy
  - Sets and Set notations

Structure hierarchy

- A recurrent theme in mathematics is the classification of spaces by means of *structure-preserving maps* between them.
- Space = set + some structure

Lie Group	Lie Algebra
Symplectic manifold	Algebra
Riemannian manifold	Vector space
Smooth manifold	Field
Topological manifold	Group
Set	