

SCE 594: Special Topics in Intelligent Automation & Robotics

Lecture 1: Course Introduction

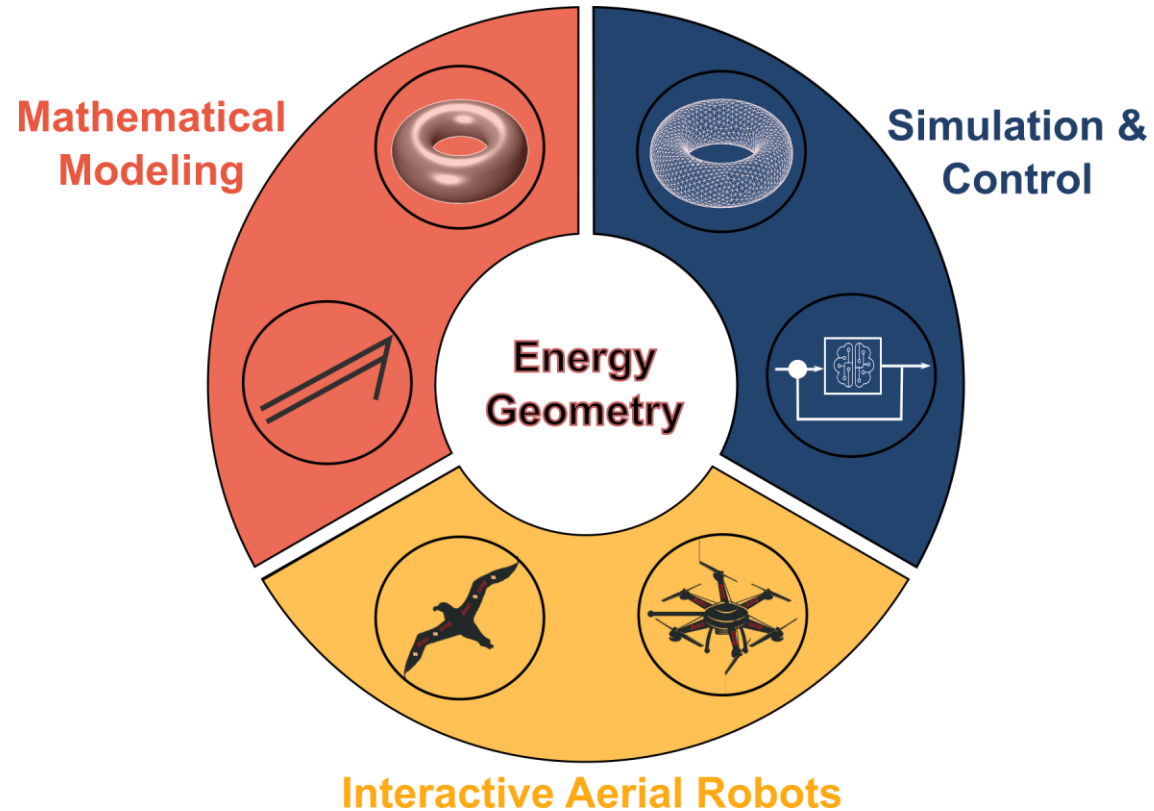


About Me

- 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

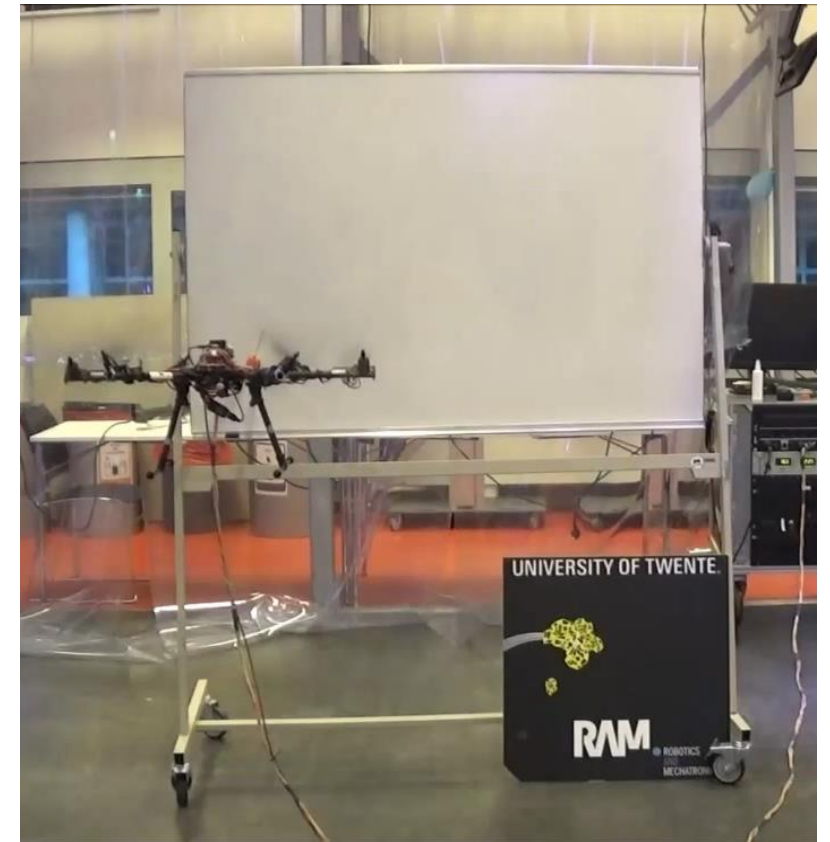


My Research



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Research Opportunities Available !!

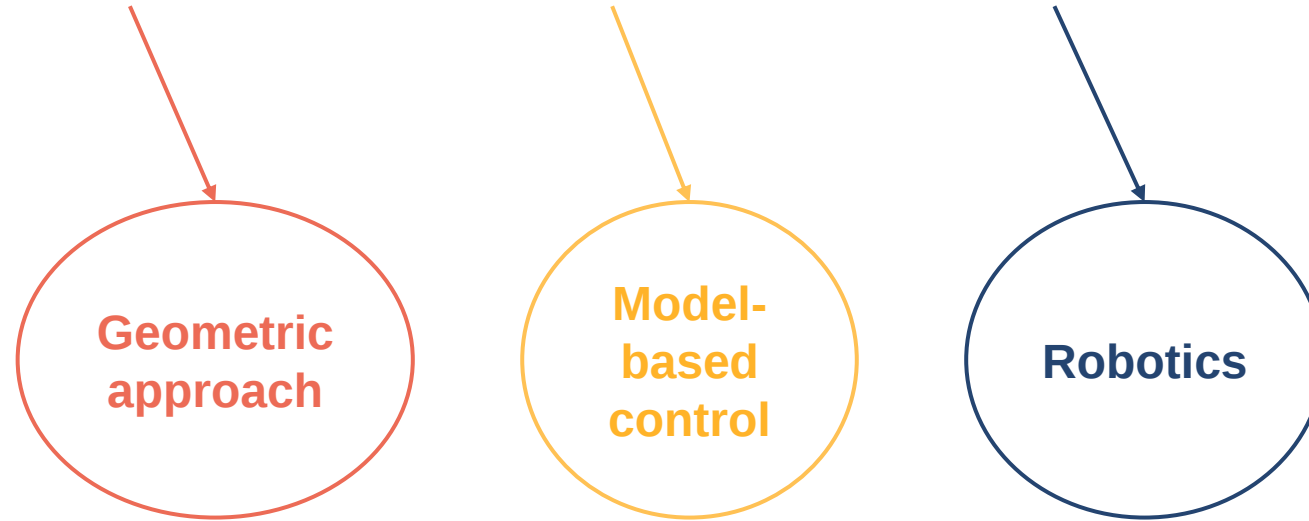


SCE 594 Course

Special Topics in Intelligent Automation & Robotics

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Geometric Control of Robotic Systems



Robotic Systems

- Multi-rotor aerial vehicles
- Fixed-based manipulators
- Floating-base manipulators
 - Ground, Aerial, Underwater



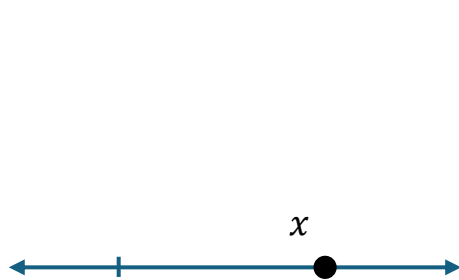
Why Geometric approach ?

- 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.

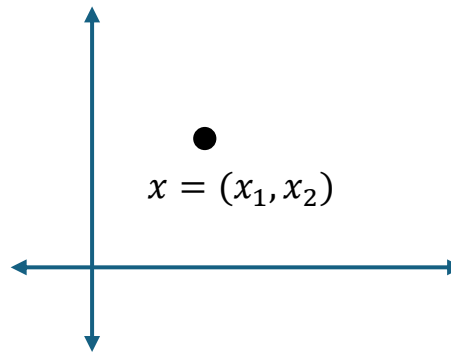


Why Geometric approach ?

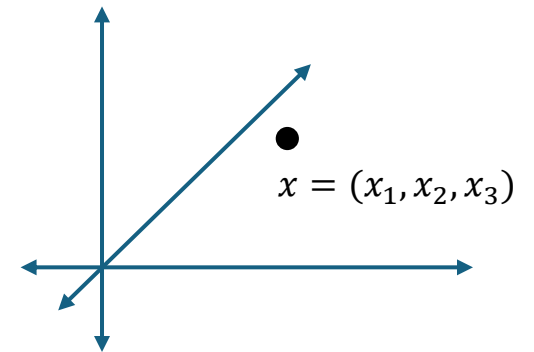
- Geometric modeling and control uses tools from **Differential Geometry**.
- Differential geometry is a branch of mathematics focusing on **non-Euclidean spaces** & **coordinate-invariance**.
- Majority of Engineering education focuses on coordinate-based Euclidean geometry.
- Euclidean space $\mathbb{R}^n$



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



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

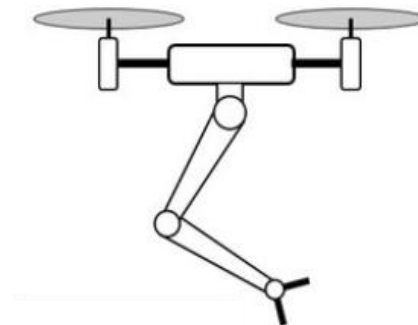
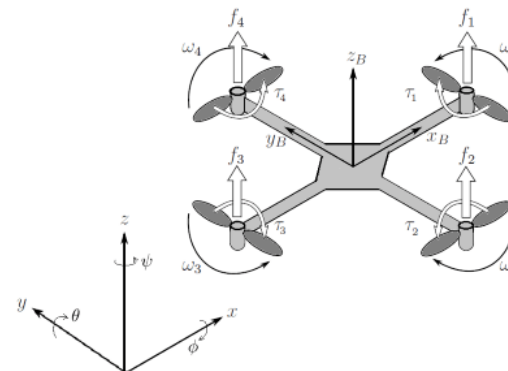
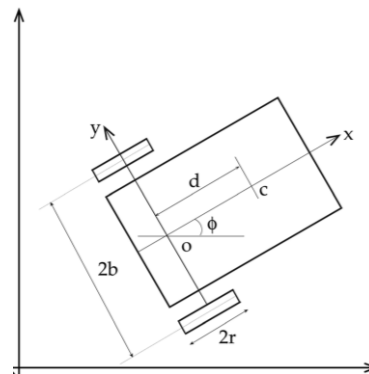
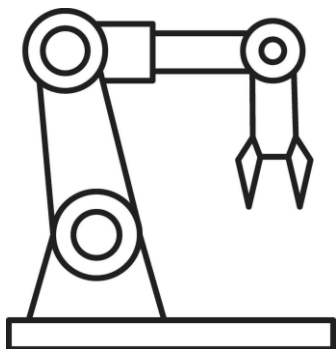
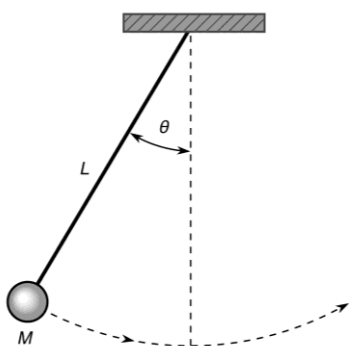


Plane $\mathbb{R}^3 = \mathbb{R} \times \mathbb{R} \times \mathbb{R}$



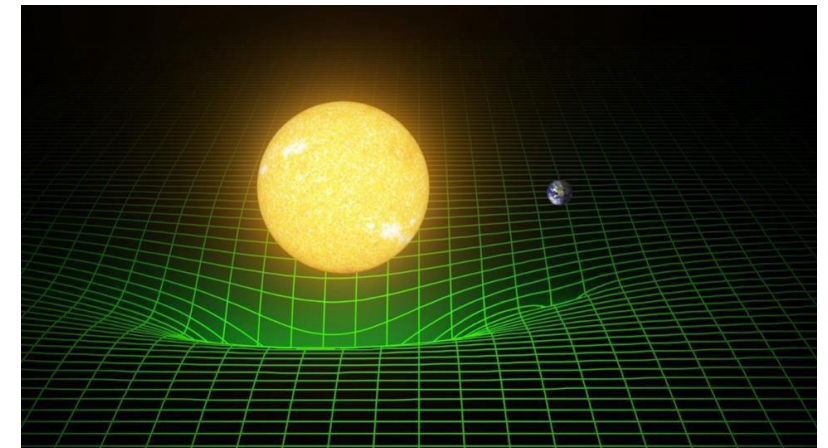
Why Geometric approach ?

- 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



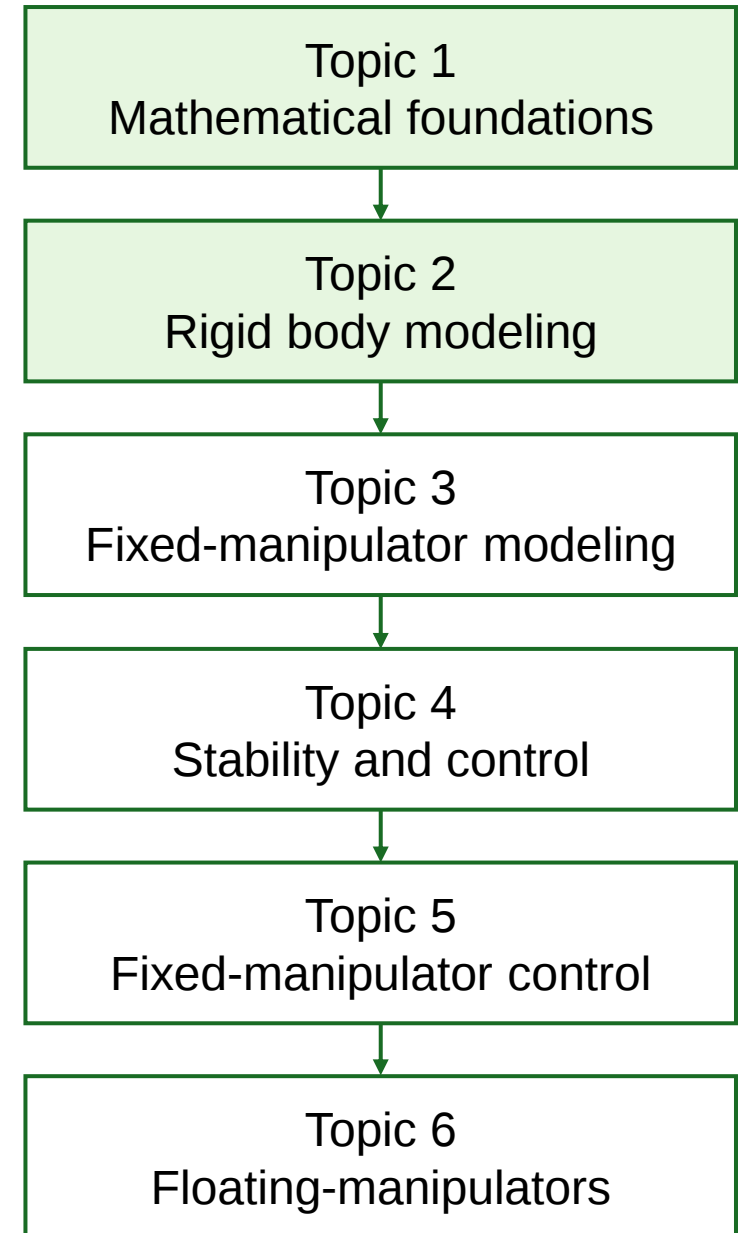
Course Topics

1. Mathematical foundations

- Set theory
- Abstract linear algebra
- Group theory
- Manifold theory
- Lie group theory

2. Rigid body modeling

- Configuration space
- Kinematics
- Dynamics



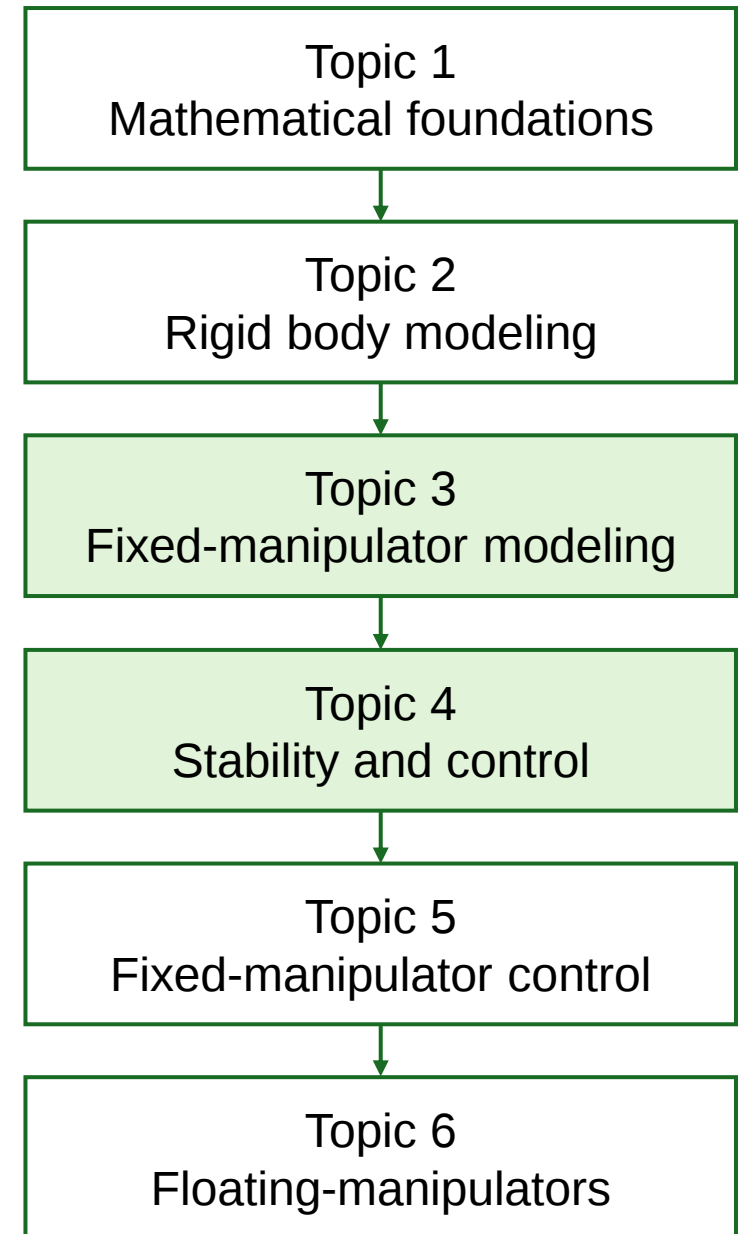
Course Topics

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



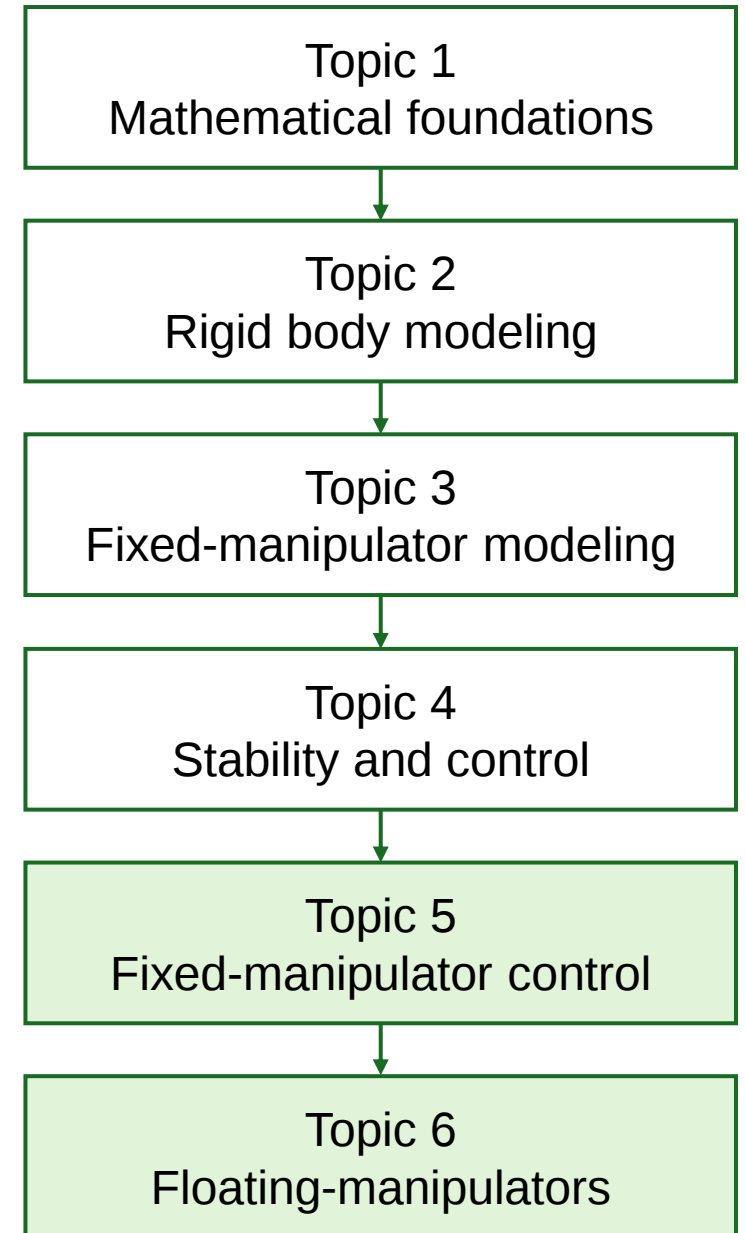
Course Topics

5. Fixed-base manipulator control

- Motion control
- Force control

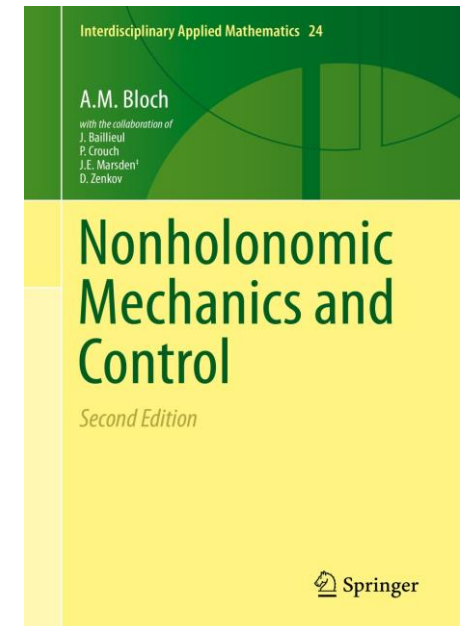
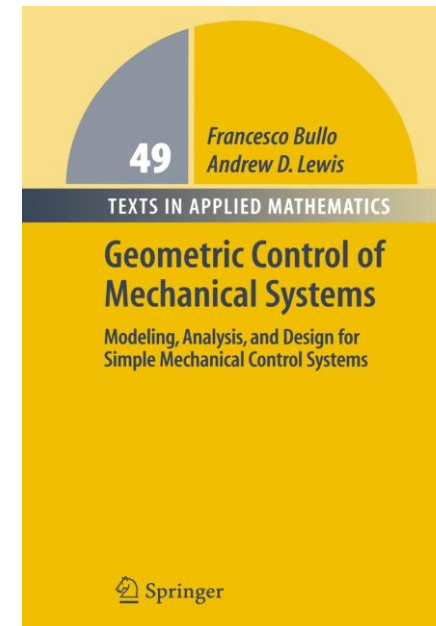
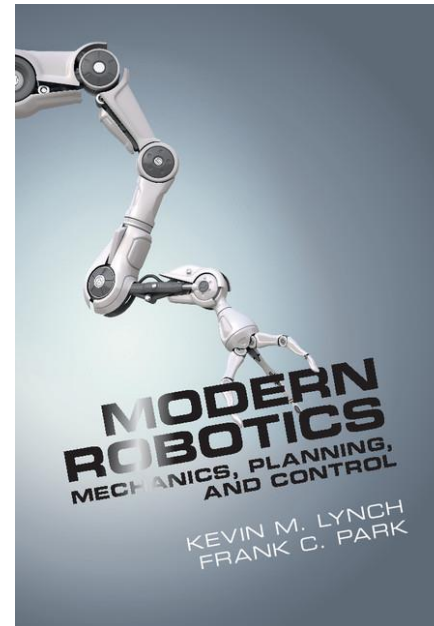
6. Floating-base manipulator

- Configuration space
- Principal bundles
- Forward kinematics
- Dynamics
- Whole-body impedance 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

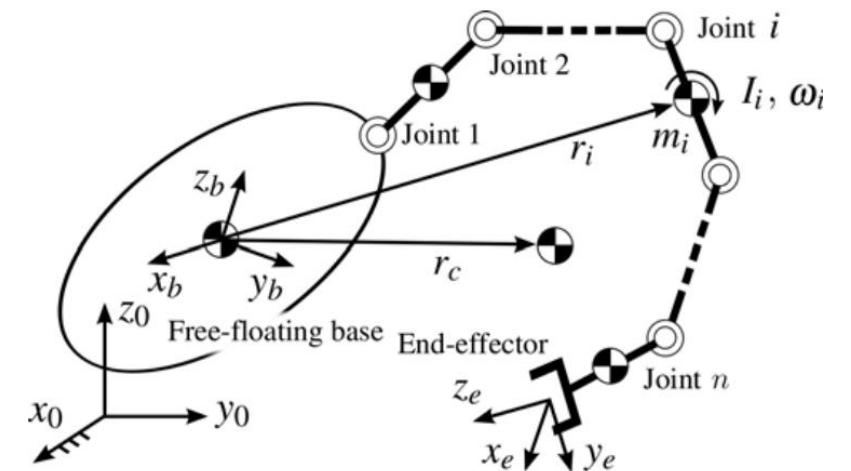


Course Assessment

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

Group Project:

- Model-based control
- Motion & Force 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 ?





FASTEN SEAT BELTS



Outline

- Course Focus
- Why Geometric approach
- Course Logistics
- Topic 1: Mathematical foundations
 - Structure hierarchy
 - Set theory basics
 - Maps between sets



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	

