Motion Planning

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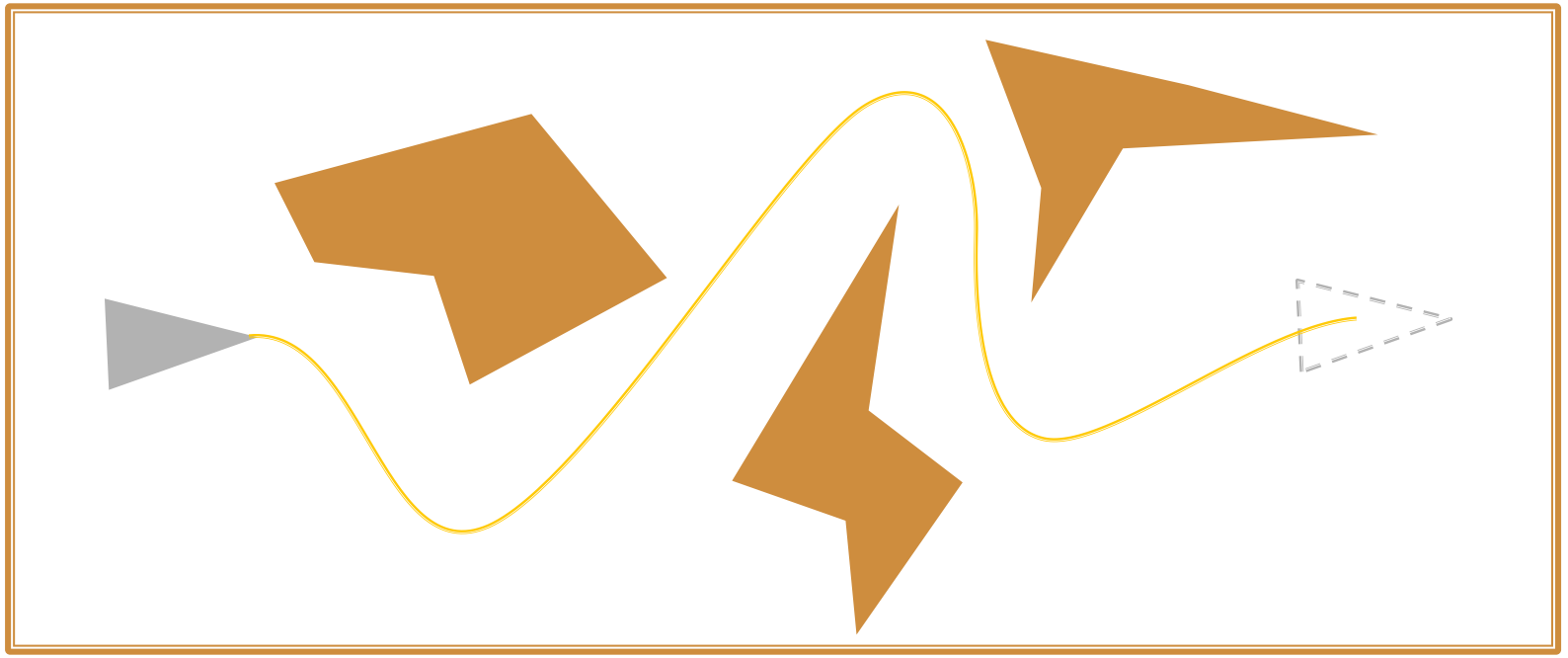
Overview

- Introduction
- Course logistics

What is motion planning?

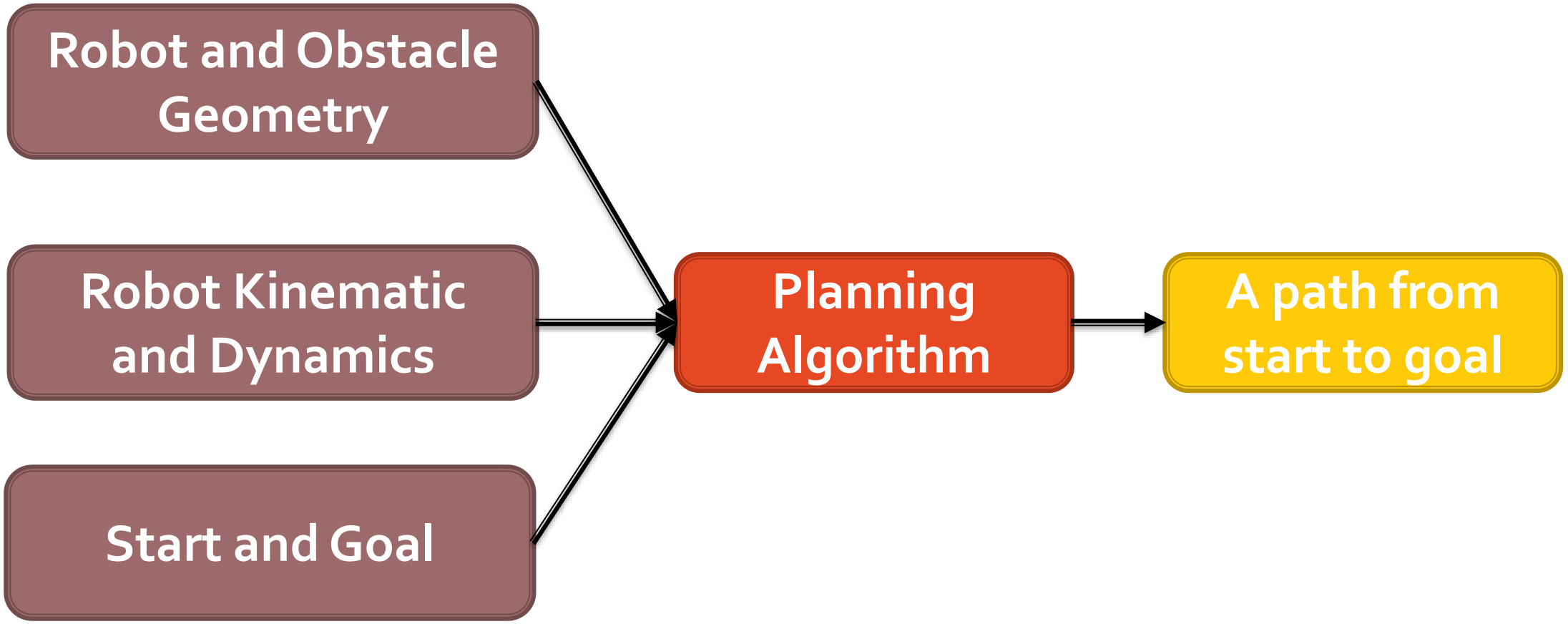
- The automatic generation of motion
  - Path + velocity and acceleration along the path



More than Obstacle Avoidance

- Path planning
  - Low-frequency, time-intensive search method for global finding of a (optimal) path to a goal
- Obstacle avoidance (aka "local navigation")
  - Fast, reactive method with local time and space horizon
- Distinction: Global vs. local reasoning

Basic Problem Statement



Basic Motion Planning Problem

Motion planning theory

- Motion planning algorithms
  - Intersection of **Robotics, Control theory, AI**
  - Planning in **discrete and continuous space**
  - Consideration for **uncertainty, differential constraints, dynamic environments, human users …**

From theory to practice

In theory, *there is no difference between theory and practice*. But, in practice, there is.

Applications

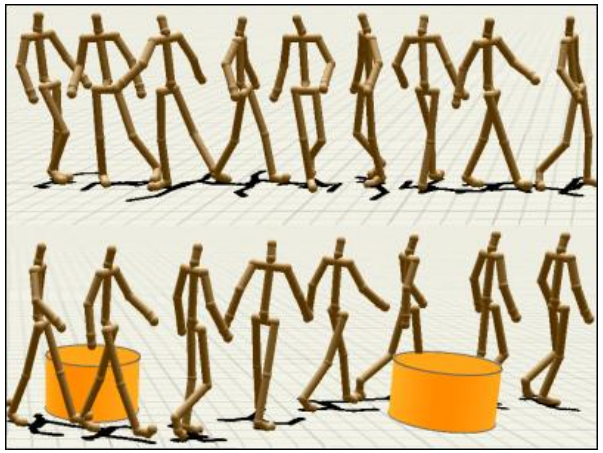
Applications

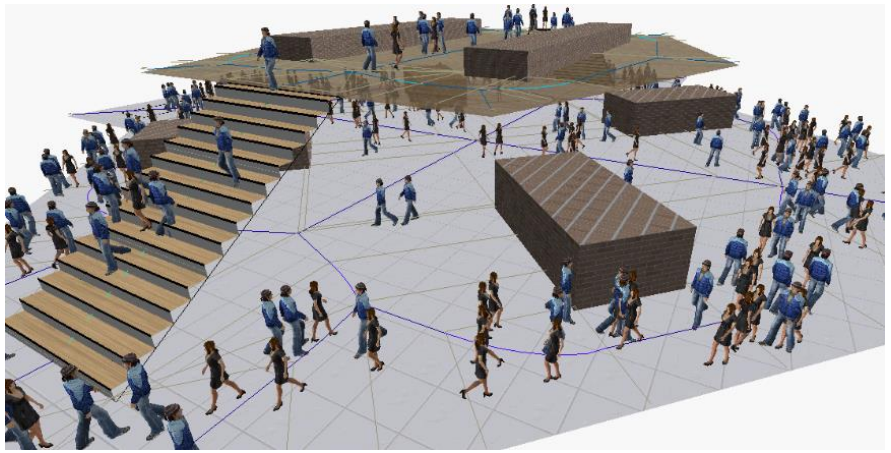
Applications

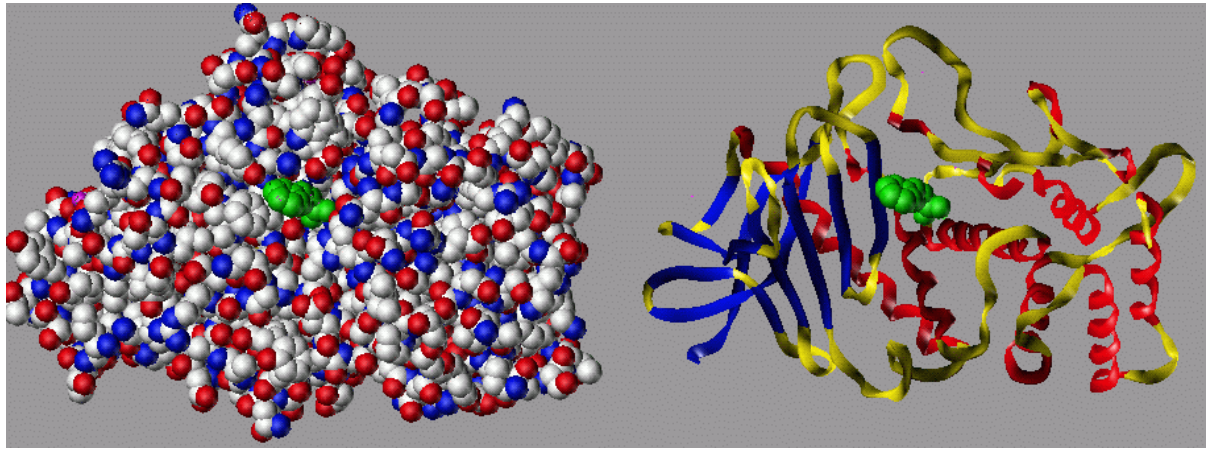
Applications

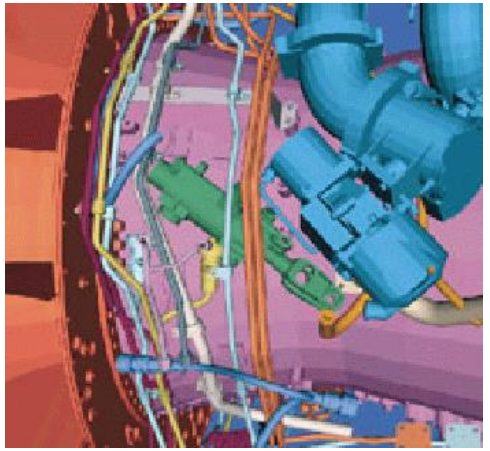
Applications – Motion Generation

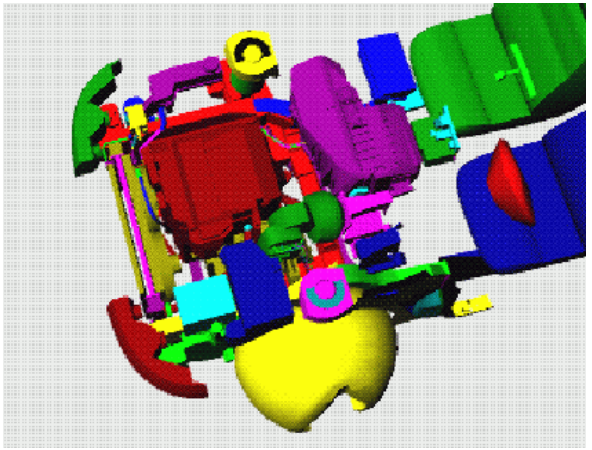
Application



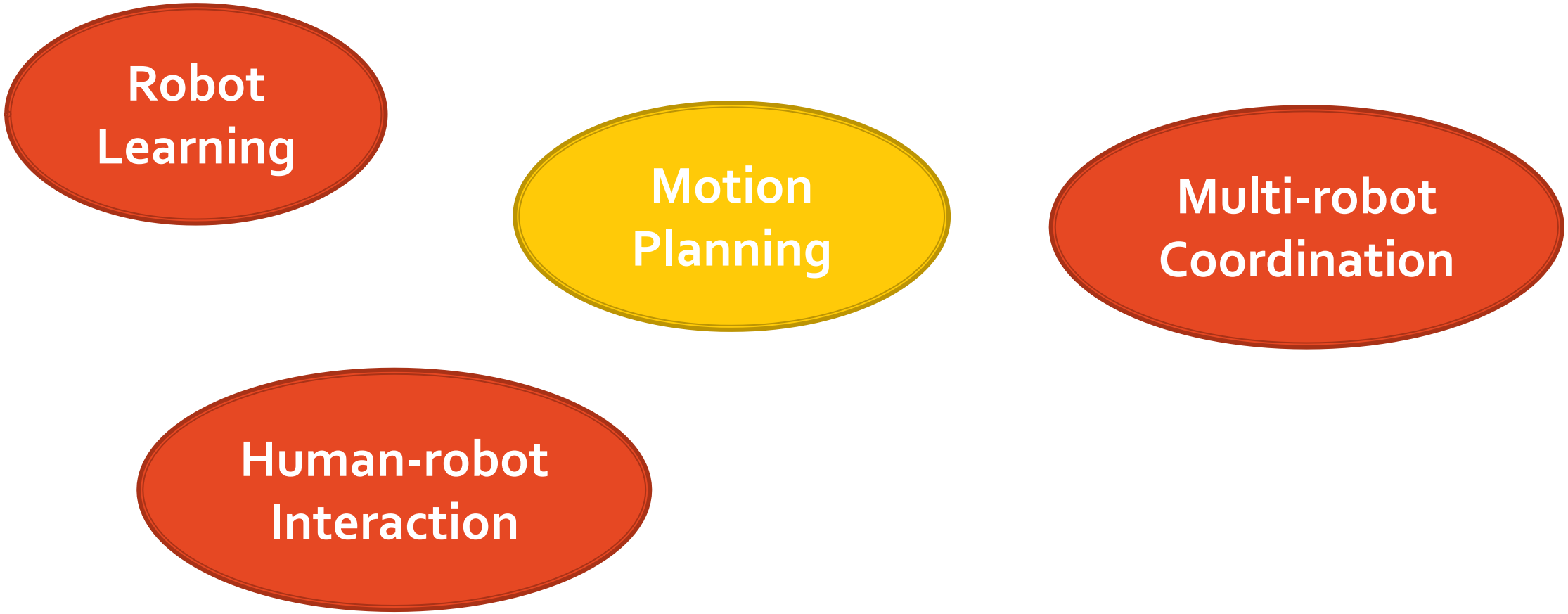








Related Areas



Course logistics

Instructor

- Research website
  - http://users.wpi.edu/~zli11/index.html
- Office hour
  - 85 Prescott 223C
  - 2:00-3:00pm, Wednesday
- Interested in lab research
  - Come to talk to me during office hour

Course website

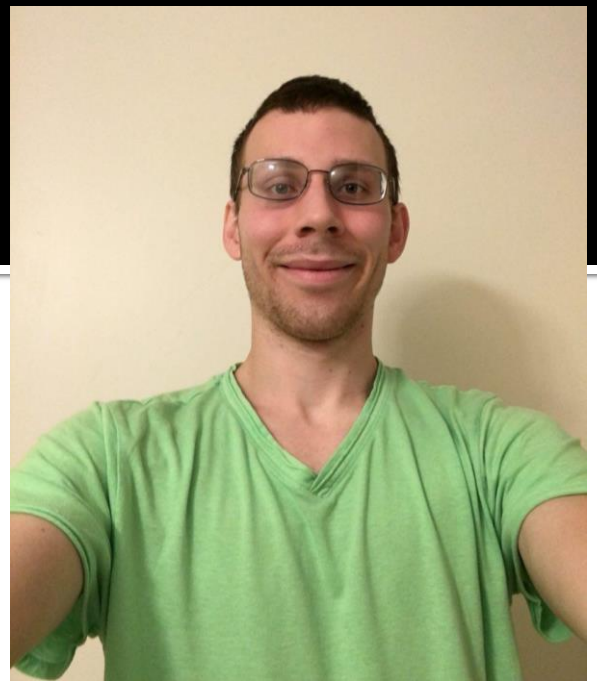
- Course website
  - http://users.wpi.edu/~zli11/rbe550_2018.html
  - Course syllabus and schedule
  - Textbook & Reference resources

- Piazza Discussion forum
  - https://piazza.com/wpi/spring2018/rbe550/home
  - For course relevant discussion

Course website

- Canvas
  - Post course materials (slides, tutorials, assignments & solutions, reference papers coursework examples)
  - Coursework submission
  - Up-to-date grades

Our TA



- Gunnar Horve (gchorve@wpi.edu)
  - Grade assignments and quizzes
  - Record class participation
  - Help with class management, project mentoring and evaluation
- TA Office hour: 2:00-3:00 pm every Wednesday
  - Answer your questions on course topics, grades
  - Help you with course projects

What you expect to get from this course

- Theory and practice of motion planning
  - Fundamental concepts and methods in motion planning
  - Applications on various robotic system
- Theoretical topics
  - Combinatorial & Sampled based motion planning
  - Robot Kinematics, Collision checking and avoidance, Trajectory planning
- Practical topics
  - Motion planning in the presence of constraints and uncertainty
  - Motion planning for arm, hand, mobile base, multi-robot system
  - Integration of motion planning with robot learning and human-robot interaction

Pre-requisites

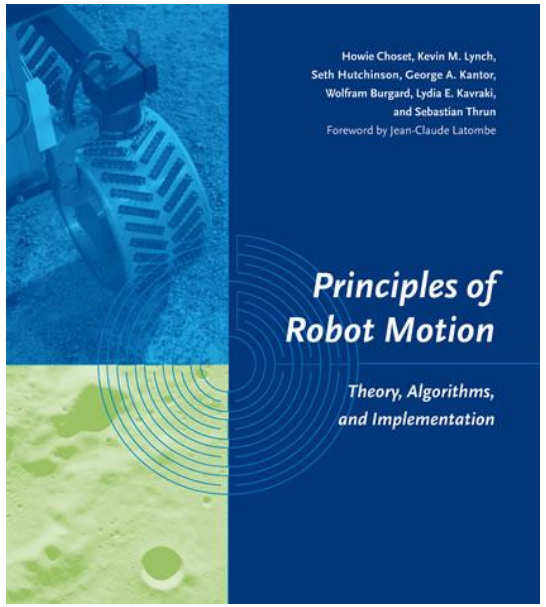
- Math
  - Linear algebra
    - Matrix operations, dot products, cross products, etc.
    - A review of linear algebra: http://cs229.stanford.edu/section/cs229-linalg.pdf
- Linux OS, bash commands, Git
- Python Coding
  - Assignments – can be done in Matlab
  - Project coding – all in python!
- You may struggle if you don't know it well

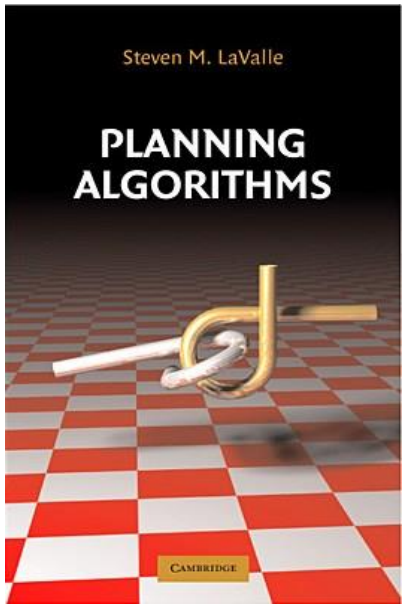
Recommended skills

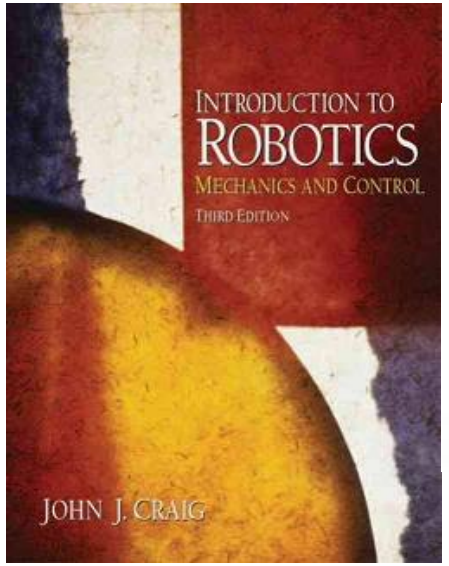
- Big plus if you know it well
  - Data structure and algorithm (e.g., how to search)
  - Robot kinematics
  - ROS, and ROS-based software (MoveIt, GraspIt)
  - Motion planning software (Klampt)
  - Image processing (OpenCV)
  - Experience with real robots (Baxter, ReFlex SF hand, Mobile base)
  - Experience with RGDB cameras (Kinect, Realsense) and LIDAR

Readings

- Reference Books







- Research Papers

Syllabus

- In-Class Participation and Preparation 10%
  - Attendance to lecture 3%
  - Active participation 7%
- Quizzes 15%
- Assignments 40%
- Course project 35%
  - Project proposal 10% + Project report 15% + Final presentation 10%

Course work submission

- Policies applied to all the submission for this course
  - Assignments, project proposal, paper preview, reports, etc.

- Submission on Canvas
  - File name = use **[LastName]_[FirstName]**_[submission content]
  - Multi-file submission: include all document in a **Single** zip file
  - Single-file submission: submit file directly
  - **Team work - submit only one copy, include the names of all teammates**.

Naming protocol

- Assignments
  - [LastName]_[FirstName]_HW_[Assignment number]
- Reports
  - [LastName]_[FirstName]_Report_[Report_title]
- Paper Reviews
  - [LastName]_[FirstName]_Review_[Report_title]
  - In the post, include title and author of the reviewed paper, with a link to the paper file.

How to submit coursework on canvas?

- Go to Canvas and click on Assignments.
- Choose respective assignment and submit zip (if coding is part of the assignment) or pdf (paper review)
- You can update your post until the time of the deadline.

Submission format

- Code for assignments
  - In one sub-folder
  - Necessary documentation
- Documents in pdf formats
  - Math problem, paper review, report
  - 11pt, single-spaced, with 1-inch margins

Penalty

- Submission in an incorrect format
  - First time – warning
  - Second time – deduct 20% from the grade
  - Third time and more – Rejected without grading
- Late submission will not be accepted.

Assignments

- Weekly Assignment
  - Math problems
  - Algorithm implementation
  - Individual paper review
- Semester assignment
  - Group paper review

Individual Paper Review

- Individual paper review assignment will be given every week
  - Assigned reading can be a paper or a short section from reference book
  - Prepare a 6-8 pages presentation slides
  - Express your in-depth understanding either in slide **notes**, or submit an additional paper review report
    - No more than 2 pages, may include figures
    - Guideline for paper review – see course website

https://docs.google.com/document/d/1AipcpudCY48TmTwt2iOrt77LMgQnsHnmmNmMHOC2Nxg/pub

Group paper review

- Each project team should conduct a literature survey
  - Must be on motion planning
    - Need instructor approval
    - No need to be relevant to your project focus
  - Read 10+ papers in depth on this topic
    - Divide the task among teammates
    - Start early and continue weekly discussion
  - Compose a 10-page literature survey report
  - Deliver a 20-min presentation
    - See course schedule for the dates of **student talk on special topic**.

Presentation for individual paper review

- Select four best paper reviews from the class
  - Receive 100% for that paper review assignment
- Choose one to give a 5 min talk in every class
  - Reward for talk – replace one quiz/assignment grade with 100% (any one you choose)

Presentation for group paper review

- In-depth understanding of the paper your reviewed
  - Tentatively 20 minutes long + 5 minutes of questions
  - Similar to a conference talk

- Evaluated on
  - Depth of understanding
  - Clarity of presentation
  - Presentation skill (don't run out of time!)

Quiz

- Quiz every lecture!
  - The beginning of the course
- Study for quiz
  - Review previous lecture slides
  - Do assignments
- Make sure your hand-writing is readable

In-class Participation

- Participation matters!
- Attending lectures
  - Count your attendance by quiz submission
- Ask and answer valuable questions **in class** and **on Piazza**
  - TA will take notes in class and count Q&A on piazza
- Help each other in projects
  - Teammates will evaluate each other)

In-class participation

- To avoid miscalculation:
  - Check with TA for your participation records
  - Keep a log for your work
- Submit a note by the end of the course
  - A one-page description of how you have helped teams/classmates
  - Include a paragraph in project report to describe your contribution

Course project

- This course is research-focused and project-orientated.

- Prepare you for doing independent research
  - Choose a topic based on your research interest and background
  - Propose methodology (e.g. experimental protocol, algorithms)
  - Implementation is necessary

Choose your course project

- Select among the projects offered by the course
  - Introduction to course project – Lecture on Jan 17
- Make your decision for course project
  - Fill project selection form
  - First, second and third choices
  - Justification for your choice
    - Previous course work, project experience
  - Preferred teammates
    - List three, with student's name, major, contact email

Project Team

- Instructor will assign project team based on
  - Student's choice & skills
  - Whether there are enough students to form a team
- Team size is proportional to project workload
  - 5-6 members per team

Project Team

- As a team you should …
  - Elect a team leader
  - Meet with instructor weekly for project discussion

- Your project will be evaluated by …
  - Mandatory – Project proposal, report, presentation, demonstration
    Optional, but highly recommended: research log, project website
    - Show the project website to your future employer/graduate advisor

Project Peer-review

- Guideline for project peer-review
  - https://docs.google.com/document/d/e/2PACX-1vT-XeAn5aUwNF9JxYz8wfvKICHFaoNbhLDaKMjYj139xFEmiLSvYLK_g2ITIVHKNu03q-dScU0F3AAq/pub

- Help you to structure and evaluate your own project proposal and final reports

Important!!!

- Submitted before **noon** of the due date.
  - Do not count late submission
- Check **Course Schedule** *frequently* for most up-to-date submission date
- Check **your grade** *frequently*. Before the end of the course, you can
  - Attend **office hour** if you need help
  - Ask for **extra work** if you want to make up for your low grade
- Keep in touch with instructor, TA, project team
  - Make sure you teammates know what you are working, because **they will evaluate you in the end**.

Academic integrity

- WPI policy
  - https://www.wpi.edu/about/policies/academic-integrity
  - Same penalty for all members involved.
- Do not risk your future

Welcome and enjoy!

Assignment 1 – Part 1 (Due on Jan 17)

- Introduce yourself to this course:
  - https://goo.gl/forms/8C7CGjZspIryl6xz1
- Make sure you can access this course on Piazza and Canvas
- Check the course syllabus and schedule
- Read **Chapter 1** in the *principles of robot motion* (referred as "principles" in the future)

Assignment 1 – Part 2 (Due on Jan 19)

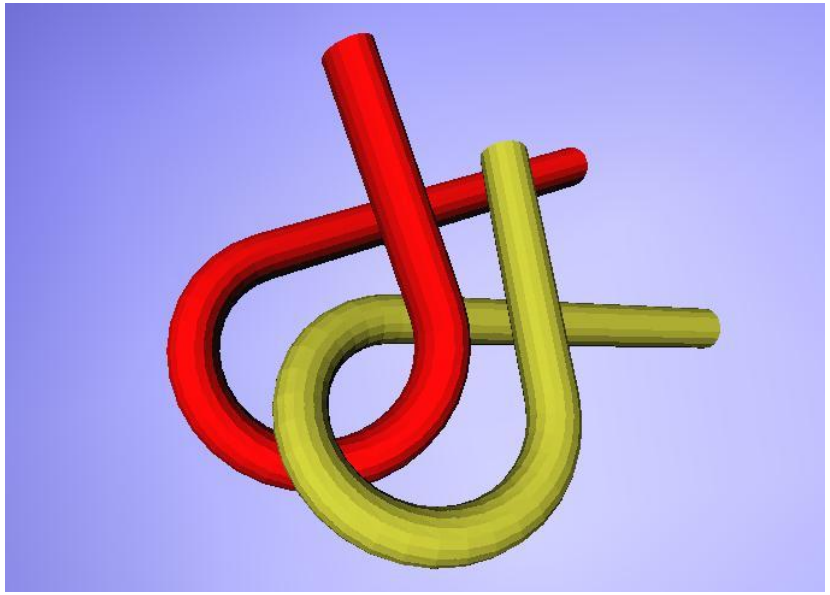
- Choose your course project https://goo.gl/forms/lIocqbABTweAur1g1

Announcement - RBE Colloquim

- Speaker:
  - Nathaniel Goldfarb (PhD)
- Date & Location
  - Jan 18, at GatePark 1002
- Title
  - Development of home-based stroke rehabilitation system of high customizability and adaptability
- RBE550 Project
  - Online motion planning in dynamic virtual environment

End

A hard problem



Basic Motion
Planning Problems