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

Robot and Obstacle Geometry

Robot Kinematic and Dynamics

Planning Algorithm

A path from start to goal

Start and Goal
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 ...
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

Robot Learning

Motion Planning

Multi-robot Coordination

Human-robot Interaction
Course logistics
• 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
- Course syllabus and schedule
- Textbook & Reference resources

- Piazza Discussion forum
  - 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.

• 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, GrasplIt)
  - 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 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/1AipcpudCY48TmTwt2iOrt77LMgQnsHnmmNmMHOC2Nxf/pub
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.
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)
• 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
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-dScUoF3AAq/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](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/8C7CGjZsplryl6xz1](https://goo.gl/forms/8C7CGjZsplryl6xz1)

• 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/llocqbABTweAur1g1
Announcement - RBE Colloquium

- **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
Basic Motion Planning Problems