EN530.678 Nonlinear Control and Planning in Robotics Project

April 2, 2021

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1 Overview

The goal of the course project is to study the trajectory generation and tracking control of a practical robotic system. This will be accomplished by deriving an analytical and algorithmic solution of the problem, implementing it in software, and demonstrating its operation in simulation. You are free to choose a specific control system and problem scenario based on your interests. If you are already involved in an existing project or application area that relates to the techniques we have studied, feel free to use it in your project.

Otherwise, a suggested list of example problems is provided below. You can work on a project either individually, but it is recomended that you team up with another student; teams can have no more than two students. While the work of a team can be divided between the two students, each member must be able to present and discuss the entire project.

2 Guidelines

1. Select a nonlinear control system that includes the following properties
   (a) underactuation or nonholonomic constraints, or otherwise non-trivial dynamics
   (b) subject to state constraints arising from e.g. obstacles in the environment
   (c) subject to uncertain disturbances (optional, for extra credit)
2. Develop a trajectory generation algorithm which computes a desired trajectory to a given desired goal region, such that:
   (a) the trajectory minimizes a given cost metric, e.g. time, distance, or energy
   (b) the trajectory satisfies given constraints, e.g. does not collide with obstacles
   (c) the planning method could combine the following techniques:
      i. local trajectory generation (i.e. between intermediate waypoints) which could rely on structures such as differential flatness, invariant primitives, etc...
      ii. optimized trajectory generation reaching the goal region using one of the following methodologies:
         - gradient-based constrained trajectory optimization
         - stochastic trajectory optimization
         - graph/tree-search based methods such as D*, RRT, PRM, etc... (optional)

3. Develop trajectory tracking control laws to follow the computed trajectory in part 2. Methods based on classical linearization, feedback linearization, backstepping, Lyapunov redesign will be applicable.

4. Implement part 2 and part 3 to demonstrate the solution of a practical problem scenario. You can use Matlab or Python and implement the system using only standard Matlab functions as well as the code used in homeworks. You can also rely on existing packages for trajectory generation such as DDP and ACADO. It is OK to employ virtual environment such as ROS/Gazebo, but not required.

3 Suggested Projects

1. Planning and control of a robotic manipulator among obstacles and subject to external uncertain disturbances, e.g. applied at the manipulator tip

2. Planning and control of an unmanned aerial vehicle (UAV) such as a helicopter or quadrotor in 3-D among obstacles

3. Planning and control of a nonholonomic (e.g. car-like) robot among obstacles

4. Planning and control for a mobile manipulator (a manipulator mounted on a mobile robot) among obstacles

5. Attitude planning and control of a satellite subject to sun-camera angle avoidance constraints, with: 1) two momentum wheels, 2) three momentum wheels subject to uncertain disturbances

6. Planning and control of a unmanned surface vehicle (USV) among obstacles, subject to 1) underactuation: e.g. modeled as a motor-boat with two propellers, or 2) full actuation and subject to external uncertain disturbances.

4 Deliverables and Schedule

Tasks and due dates are as follows (use the File Upload form to upload all files by due dates)

Dates	Task
4/16	Form teams and discuss proposed project with TAs or instructor
4/21	Upload Proposal Summary Slides (2 slides)
5/12	Present Final Project during Final Exam Slot 9-12am (5 min. per team)
5/15	Upload Project Report (max 6 pages)

You can sign up for an optional 5-minute slot to discuss your project with the Instructor `https://docs.google.com/spreadsheets/d/1XUdFIswHwwFB8Gxg2rvarZP8URk7PFcZvWImcJ_J4es/edit?usp=sharing`[here].

For your project presentations and report, make sure that you include performance graphs of the implemented trajectory generation and control laws, such as stabilization/tracking error as a function of time, or if you include obstacles, distance to obstacles. If you are considering uncertainty, you can analyse the performance as a function of uncertainty magnitude.