Department of Mechanical Engineering
Cleveland State University

MCE/EEC 647/747: Robot Dynamics and Control
Call for Term Project Proposals

1 or 2-page project proposals due Friday, April 3, 5PM (email).

Schedule

Experimental projects involve 1 or 2 students. Simulation/theory projects must be individual.

- Proposals due Friday, April 3, 5PM. 2 pages max, with a few relevant references.
- Final proposal commitments defined on Tuesday, April 7th.
- Experimental projects with CRML hardware require lab time outside class, mostly unsupervised.
- Project presentations (optional for 647 students, mandatory for 747): Non-experimental projects: April 28th and April 30th. Attendance mandatory.
- Project presentations, experimental projects (experiment demo optional, attendance optional): to be scheduled during finals week.
- Project reports due May 8th by 5PM, no exceptions.

Project Menu

General rule: Projects must involve some topics and techniques learned in the course. Advanced concepts and techniques and applications not studied in class are welcome, and in some cases necessary. Emphasis must be placed on control and dynamics rather than kinematics.
There are two main categories: experimental projects and paper projects. Sub-categories and rules as follows:

Experimental Projects

1 or 2 students work on a project with an experimental implementation as a goal.

- Selected by students: Experimental work and final demonstration to be carried out in the student advisor's lab.
- Suggested by instructor: Experimental work and final demonstration to be carried out at CRML. Only a few experimental projects can be supported.

Paper/Simulation/Theory Projects

Students must work individually. The topics can be selected by the student or students can choose one of the topics suggested by the instructor.

- Paper analysis: A published technical paper with clear simulation results is selected. The student must follow the derivations and fill in for details not included in the paper. The goal is to apply the techniques of the paper to reproduce the results. Paper critique and suggestions for improvement or new research are essential.
- Simulation/design: This kind of project is instructor-driven. The student will be asked to design, tune and simulate two different advanced controllers (learned in the course) for a trajectory control task with a given robot.
- Theory: A new problem related to robot control must be formulated and a solution must be proposed. This is an open-ended project, and can be instructor-driven or selected by the student. Note that numerical optimization without analysis does not count as theory.

Suggested Projects

More details to be provided once students commit to a project.

Experimental

IE1 **Development of a safety control system for the PUMA robot:** When testing or tuning candidate controllers, unstable behavior can occur due to implementation or theory errors. The robot can move fast and unexpectedly and destroy itself by crashing into the lab floor. This violates one of Asimov's laws of robotics and the ME department budget. The objective is to invent a way to detect danger (understood as an unadmissible combination of position and velocity) and switch to a safety controller which will prevent the end effector to come close to the ground and will stabilize the robot. Switching must be guaranteed (by analytical means, not by one simulation example) to be smooth and switchback must be disallowed.**2 groups of 1 or 2 students can work on this in parallel, but solution approaches must be very different**.

IE2 **Joystick-driven Cartesian trajectory-following for the PUMA robot**: A 3-axis joystick will be used to provide a real-time Cartesian trajectory for the end effector. The system must solve inverse kinematics online and build a set of jointspace trajectories to be fed to a robust controller. This involves some research on making joystick angles available in real-time for the dSPACE system.

IE3 **Stabilization of (underactuated) Furuta Pendulum (747, 747+747 or 747+647)**: A rotary platform driven from a DC motor with encoder is available in the lab. Minimal machining will be required to make a pendulum and hinge and to attach an encoder to the pendulum. A published paper will be selected that contains a suitable technique to stabilize the pendulum in the upright position from any initial condition. Of course, a new solution is welcome, but this is a very difficult problem.

Simulation/Design

IS1 : **PUMA robot:** Design a passivity-based robust and a passivity-based adaptive controller to track trajectories with a 4 DOF PUMA model. This includes finding the regressor. Realistic model parameters and will be given, as well as limitations on the magnitude of the control inputs.

IS2 : **Hip robot:** Design a passivity-based robust and a passivity-based adaptive controller to track trajectories with a 3 DOF model of CSU's hip robot. This includes finding the regressor. Realistic model parameters and will be given, as well as limitations on the magnitude of the control inputs.

IS3 : **Drone tracking:** Open-ended: Design a hypothetical system (robot+trajectory controller) to keep a drone in line of sight. Only delayed measurements of the drone's position are available. The drone's trajectory is not known in advance, but can be assumed twice differentiable in time. This project must involve research for papers with a similar problem and must be presented on April 28 or 30.

IS4 : **Numerical optimization of robots with energy regeneration:** Related to instructor's research. The idea is to determine the optimal impedance parameters for robots with certain regenerative electronics. Only impedance controllers are considered. Only numerical optimization is to be attempted.

Theory

IT1 : **Closed-form optimization of robots with energy regeneration:** Related to instructor's research. The idea is to determine the optimal trajectories, optimal parameters and hypothetical optimal forces for robots with certain regenerative electronics. Only trajectory-tracking controllers are considered. Only closed-form solutions are sought.

IT2 : **Analytical/numerical optimization of robots with energy regeneration:** Related to instructor's research. The idea is to determine the optimal impedance parameters for robots with certain regenerative electronics. Only impedance controllers are considered. Closed-form solutions are not likely, but variational calculus can be used to reduce the problem to numerical solution PDE or ODE solutions. Knowledge of optimal control with variational calculus methods is preferrable.