AMR 2014/2015: Final Projects

A final project entails:

- reading some literature and/or documentation on a specific subject
- performing simulations or numerical tests on a software platform (MATLAB, V-REP,...)
- writing a report
- giving a presentation (with slides)

As a rule, each project must be carried out by a group of **3 students**. Projects are assigned to groups on a FIFO basis. Send me an e-mail message (directly, not through the Google Group) specifying **at least 3** projects in which your group is interested, with an order of priority, and the composition of the group. One or two-persons groups can also apply, but I reserve the right to merge them to a larger group. Once your group has been assigned a project, we will set up a meeting to discuss the project in detail.

Two larger projects (1 and 2) are **shared** with **Robotics 2**; this means that they are simultaneously valid as final projects for both courses.

The deadline for applying for a project is **June 6**. Late applications will not be accepted. There will be three deadlines for submitting your projects: **July 10**, **September 30**, **December 31 (2015)**. To submit your project, send me an e-mail with the report. Once a deadline is passed, I will fix a common date for presenting all the projects completed during the associated time window.

This is the list of the available projects:

1. Task control of a nonholonomic mobile manipulator (shared with Rob 2)

2. Modeling and control of a quadrotor with tilting propellers (shared with Rob 2)

3. Humanoid walking motion generation: compensation schemes

4. Humanoid walking motion generation: preview control schemes

5. Formation control of a team of mobile robots

6. Generating reaching motions for a humanoid

7. Planning transfers between equilibria for a Pendubot

8. Stack of Tasks approach for humanoid task control

9. Predictive task control for a nonholonomic mobile manipulator

10. Planning transfers between equilibria for a quadrotor

11. Implementation of feedback controllers for unicycle robots

A short description of each project follows.

1. Task control of a nonholonomic mobile manipulator (shared with Rob 2)

Synopsis
The aim of this project is to build in V-REP a model of a nonholonomic mobile manipulator composed by a car-like vehicle equipped with an elbow-type 3R arm, and to implement two possible approaches for task control. The first is based on input-output feedback linearization with the inclusion of null-space commands. The second is based on dynamic feedback linearization. A critical comparison based on simulations should be performed.

Reading material
De Luca et al, "Kinematic Control of Nonholonomic Mobile Manipulators in the Presence of Steering Wheels," ICRA 2010
V-REP software documentation

2. Modeling and control of a quadrotor with tilting propellers (shared with Rob 2)

Synopsis
The aim of this project is to build in V-REP a model of a special quadrotor that can also change the orientation of the propellers by specific actuators. This additional set of 4 control inputs yields allows the quadrotor to move as a fully-actuated flying object. Two possible approaches for motion control should be implemented. The first is based on input-output feedback linearization with the inclusion of null-space commands. The second is based on dynamic feedback linearization. A critical comparison based on simulations should be performed.

Reading material
Ryll et al, "A Novel Overactuated Quadrotor UAV: Modeling, Control and Experimental Validation", preprint
V-REP software documentation

3. Humanoid walking motion generation: compensation schemes

Synopsis
A simple approach to generating walking motions for humanoid robots is to use a linear model (Linear Inverted Pendulum). One of the limitations of this approach is that it does not consider explicitly the contribution of the swinging leg motion to the Zero Moment Point. The objective of the project is to implement and compare in MATLAB some existing solutions, and to use the results to improve a recently introduced framework for generating bounded trajectories of the Center of Mass.

Reading material
A selection of papers on compensation schemes for LIP-based locomotion
Lanari et al, "Boundedness Issues in Planning of Locomotion Trajectories for Biped Robots," Humanoids 2014

Notes
Supervisor: Leonardo Lanari

4. Humanoid walking motion generation: preview control schemes

Synopsis

An approach to generating walking motions for humanoid robots is to use a simplified linear model (Linear Inverted Pendulum). One of the most popular control schemes for locomotion is the preview control introduced by Kajita. The aim of the project is to implement in V-REP the different versions of the preview control in order to create a tool for future comparisons with other techniques.

Reading material

Kajita at al, "Biped Walking Pattern Generation by using Preview Control of Zero-Moment Point," ICRA 2003

Herdt, "Model Predictive Control of a Humanoid Robot," PhD thesis, 2013

Notes

Supervisor: Leonardo Lanari

5. Formation control of a team of mobile robots

Synopsis

The aim of this project is to build in V-REP a model of a group of mobile robots having all unicycle or car-like kinematics, and to design schemes for controlling tasks related to their formation (barycenter, variance, etc). Two possible approaches will be considered for task control. The first is based on input-output feedback linearization with the addition of null-space commands. The second is based on dynamic feedback linearization. A critical comparison based on simulations should be performed.

Reading material

De Luca et al , "Kinematic Control of Nonholonomic Mobile Manipulators in the Presence of Steering Wheels," ICRA 2010

A selection of papers on formation control

V-REP software documentation

6. Generating reaching motions for a humanoid

Synopsis

Consider the problem of generating in real time the motion of a humanoid that must reach and grasp an object. The canonical approach is to use a task controller that drives to zero the error vector between the desired and the current hand pose. With this approach, however, the hand trajectory from the start to the goal is implicitly assigned and cannot be deformed, e.g., for avoiding obstacles. The objective of the project is to apply to this problem a different approach aimed at zeroing only the norm of the error. This is convenient because it leaves the hand free to move along any trajectory that converges to the desired pose. The proposed method should be implemented and validated in V-REP using the available model of the NAO humanoid.

Reading material

Marey and Chaumette, "A New Large Projection Operator for the Redundancy Framework," ICRA 2010

V-REP software documentation

7. Planning transfers between equilibria for a Pendubot

Synopsis
A Pendubot is an underactuated 2R robot that moves in the vertical plane using a single actuator at the shoulder. Planning motions for underactuated robots is challenging due to the fact that the number of control inputs is smaller than the number of degrees of freedom. The objective of this project is to extend an existing trajectory planner for this system, already developed in Kite, from the current second-order (acceleration) to the third-order (snap) level. This will guarantee that the final configuration reached by the Pendubot is an equilibrium, so that the desired transfer is effectively realized.

Reading material
Cefalo and Oriolo, "Task-Constrained Motion Planning for Underactuated Robots," ICRA 2015
Kite software documentation

Notes
Some C++ programming skills are a plus. Supervisor: Massimo Cefalo.

8. Stack of Tasks approach for humanoid task control

Synopsis
The goal of this project is to implement and test in V-REP an approach to real-time motion generation know as "Stack of Tasks" (SOT), and to apply it to a NAO humanoid which must execute a manipulation task. In the SOT approach, all the tasks and constraints that the robot must guarantee (manipulation, collision avoidance, dynamic equilibrium,…) are stacked together and then used to formulate an optimization problem whose solution provides a feasible velocity. This greedy approach should be compared with the exploratory approach represented by an existing motion planner.

Reading material
A selection of papers on the SOT approach
V-REP software documentation

9. Predictive task control for a nonholonomic mobile manipulator

Synopsis
The goal of this project is to implement and test in V-REP a task controller for redundant robots based on the predictive control approach. In particular, the application platform will be a nonholonomic mobile manipulator composed by a unicycle vehicle equipped with an elbow-type 3R arm. The idea is to use the predictive control paradigm to compute in real-time joint velocities that are optimal over a certain time horizon (rather than at a single instant). The generated motions are expected to exploit more effectively the kinematic redundancy of the mechanism.

Reading material
Basic literature on predictive control
V-REP software documentation

10. Planning transfers between equilibria for a quadrotor

Synopsis
A a quadrotor equipped with a rigid tool is an underactuated system, because it has 4 control inputs and 6 degrees of freedom. The goal of this project is to revise and extend an existing trajectory planner for this system, already developed in V-REP, from the current second-order (acceleration) to the third-order (snap) level. This will allow to guarantee that the final configuration reached by the quadrotor is an equilibrium, so that the desired transfer is effectively realized.

Reading material
Cefalo and Oriolo, “Task-constrained motion planning for underactuated robots,” ICRA 2015
Additional notes
V-REP software documentation

Notes
Supervisor: Massimo Cefalo.

11. Implementation of feedback controllers for unicycle robots

Synopsis
The goal of this project is to implement and test in V-REP a catalogue of feedback controllers for a unicycle robot. In particular, the robot is a differential-drive vehicle with odometric localization and equipped with a GPS. Both trajectory tracking and posture regulation controllers will be considered. The selected control schemes will be all those studied in the course, with the addition of two more sophisticated trajectory control schemes. Comparison of the various controllers over a campaign of simulations is expected, both under odometric and GPS localization.

Reading material
Course slides on control of WMRs
Additional notes
V-REP software documentation