AMR 2016/2017: Final Projects

A final project consists of:

- studying some papers, notes or documentation on a specific subject
- performing simulations or numerical tests on a software platform
- 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 e-mail message specifying a list of **3** projects in which your group is interested, with an order of priority, and the composition of the group. 1 or 2-student groups can also apply, but I will merge them into larger groups. The deadline for applying for a project is **May 15**. Late applications will not be accepted.

Four projects are **shared** with **Robotics 2**; these are accessible to students that have qualified for both AMR and Robotics 2, and are simultaneously valid as final projects for both courses. Two of these shared projects are in the list below (numbers 2 and 4); two more are in the project list provided by prof. De Luca. If your group is applying for a shared project, please send an e-mail message to **both** me and De Luca.

Once your group has been assigned a project, we will set up a meeting to discuss the project in detail. There will be three deadlines for submitting your projects: **June 30**, **September 30**, **December 31 (2017)**. 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. MPC for a nonholonomic mobile manipulator

2. Planning and control of the BallBot (shared with Rob 2)

3. RRT vs RRT*

4. MPC-based visual corridor navigation for humanoids (shared with Rob 2)

5. Controlling humanoid robots in DART

6. MPC-based humanoid gait generation using Mixed Integer Programming

7. MPC-based humanoid gait generation with variable CoM height

In the following pages you fill find a short description of each project.

1. MPC for a nonholonomic mobile manipulator

Synopsis
The objective of this project is to implement and test a Model Predictive Control (MPC) approach for a mobile manipulator (MM). In particular, the robot will be a nonholonomic MM composed by a unicycle vehicle equipped with an elbow-type 3R arm. The idea is to use the MPC paradigm to compute real-time robot commands that are optimal over a certain time horizon and satisfy a number of constraints, the most important being manipulation tasks and collision avoidance. The generated motions are expected to exploit more effectively the kinematic redundancy of the mechanism w.r.t. simple kinematic control. The software platform may be MATLAB or V-REP.

Reading material
Papers on nonholonomic MMs and on MPC
MATLAB or V-REP documentation

2. Planning and control of the BallBot

Synopsis
The BallBot is an underactuated mobile robot consisting of a tall cylindrical body balancing on a spherical wheel. Planning and controlling 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 derive a model-based dynamic simulator for the BallBot and to implement a method for trajectory planning and control. The software platform may be MATLAB or V-REP.

Reading material
Papers and notes on modeling, planning and control of the BallBot
MATLAB or V-REP documentation

3. RRT vs RRT*

Synopsis
The RRT algorithm is very good at exploring configuration spaces and therefore it can plan feasible trajectories very quickly. However, the quality of these trajectories as robot motions is often quite poor. The objective of this project is to implement and test a motion planning algorithm called RRT*. This is a substantial improvement over the basic RRT, to which it adds an asymptotic optimality property. A performance assessment of the method should be made with respect to the classical RRT for the case of a unicycle robot. The software platform may be MATLAB or V-REP.

Reading material
Papers on the RRT* algorithm
MATLAB or V-REP software documentation

4. MPC-based visual corridor navigation for humanoids

Synopsis
Model Predictive Control (MPC) has emerged as an effective and robust approach for humanoid gait generation due to its constraint handling capability. The objective of this project is to use this approach in conjunction with a high-level navigation strategy based on visual cues for navigating a NAO humanoid robot within an office-like environment. The software platform is V-REP.

Reading material
Papers on MPC-based humanoid gait generation and corridor navigation
MATLAB or V-REP documentation

5. Controlling humanoid robots in DART

Synopsis
DART (Dynamic Animation and Robotics Toolkit) is an open source library for robotics. It provides a multibody dynamic simulator and various kinematic tools for control and motion planning. The objective of this project is to import in DART a humanoid robot model (NAO or HRP-4), and control the robot so as to execute a specific locomotion gait, either provided by an external module or generated within DART. To this end, it will be necessary to derive kinematic quantities (Jacobian matrices) related to the CoM and the feet of the robot. The software platform is DART.

Reading material
NAO or HRP-4 documentation
DART documentation

6. MPC-based humanoid gait generation using Mixed Integer Programming

Synopsis
Model Predictive Control (MPC) has emerged as an effective and robust approach for humanoid gait generation due to its constraint handling capability. When the constraints are linear, the control law is computed in real-time by solving a Quadratic Programming (QP) problem. The objective of this project is to investigate the use of Mixed Integer Programming (MIP) for handling non-linear constraints, typically related to footsteps rotation. This will ultimately allow to generate gaits for walking along curved paths. The software platform is MATLAB.

Reading material
Papers on MPC-based humanoid gait generation
MATLAB documentation

7. MPC-based humanoid gait generation with variable CoM height

Synopsis
Model Predictive Control (MPC) has emerged as an effective and robust approach for humanoid gait generation due to its constraint handling capability. Typically, to obtain a linear model for control computation (the so-called Linear Inverted Pendulum) one

assumes that the CoM height is constant. The objective of this project is to investigate the possibility of allowing a variable CoM height within the same approach, either by using a preassigned height profile (e.g., sinusoidal), or by including the height as an additional variable in the optimization problem. A performance assessment of the method should be made with respect to the constant-height version. The software platform is MATLAB.

Reading material
Papers on MPC-based humanoid gait generation
MATLAB documentation