# AMR 2010/2011: Final Projects

## 0. **General Information**

A final project includes:

- studying some literature (typically, 1-2 papers) on a specific subject
- performing some simulations or numerical tests on an appropriate software platform (Matlab, Webots, KiteLab); sometimes, experiments are involved
- writing a report
- making 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 (not through the Google Group) specifying **at least 3** projects your group is interested in, 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.

The deadline for project application is **June 15**. Late applications will not be accepted. There will be three deadlines for turning in your projects:

- July 10
- September 30
- December 31

To turn in 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. I strongly recommend attendance to all presentations even if you are not directly involved.

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## 1. **Inequality constraints in kinematic control of redundant robots**

**Synopsis**
Kinematic control of redundant robotic systems is often obtained by prioritizing tasks. While some of these tasks are expressed as equality constraints (e.g., following an assigned e-e trajectory), others are better represented by inequality constraints (e.g., (joint limits, collision avoidance, etc). This project is aimed at studying and implementing on a mobile manipulator a method that can handle simultaneously both types of constraints. A MATLAB implementation is recommended.

**Literature**
Kanoun et al., “Prioritizing linear equality and inequality systems: application to local motion planning for redundant robots”, ICRA 2009

**Notes**
Shared project with Robotics 2; already assigned to **Bianchi+Gualandi** (group 1) and **Imperoli** (group 2)

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## 2. Collision avoidance and reaction using Kinect

**Synopsis**
The idea is to interface and use the recently introduced Kinect device as a vision sensor to implement collision avoidance and reaction on the KUKA KR5 manipulator. Implementation in Webots and then on the actual KUKA robot.

**Literature**
Kinect libraries (OpenNI and PrimeSense) guides, OpenCV library guide
Ma et al, "An Invitation to 3D Vision", Springer

**Notes**
Shared project with Robotics 2; already assigned to **Furno+Giampieri+Ortenzi** (group 1) and **Di Cicco+Montesanti+Serafin** (group 2)

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## 3. Visual interception with the NAO humanoid

**Synopsis**
The objective is to develop a visual servoing method that allows the NAO humanoid to detect and intercept a possibly moving target. A possible approach, originally proposed for a wheeled mobile robot, is to control the head to track the target and then follow the head with the rest of the robot body. Implementation in Webots and then on the actual NAO robot.

**Literature**
NAO documentation
Freda and Oriolo, "Vision-based interception of a moving target with a nonholonomic mobile robot," Robotics and Autonomous Systems, vol. 55, pp. 419-432, 2007

**Notes**
Shared project with Robotics 2; already assigned to **Basile+Franceschi+Fabrizi**

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## 4. Footstep planner for the NAO humanoid

**Synopsis**
Most humanoid robots, including NAO, walk using a method based on the control of the Zero-Moment Point (ZMP). In fact, if the ZMP falls within the support polygon then the robot is in dynamic equilibrium. In this approach, the footstep planner generates first the footsteps and then a motion of the ZMP satisfying the above constraint. In particular, the NAO footstep planner generates the ZMP reference trajectory by interpolating the reference points linearly and assuming a timing law with bang-coast-bang acceleration profile. The objective of this project is to try other kinds of geometric paths and timing laws, and study their effect on the walking performance. Implementation in Webots.

**Literature**
NAO documentation
Kajita et al, "Biped walking pattern generation by using preview control of zero-moment point," ICRA 2003

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## 5. Joystick-based remote control of the NAO humanoid

**Synopsis**
The current footstep planner is provided by the C++ method add(x, y, a), where (x, y) and a are respectively the position and orientation of the new footstep with regards to the previous. The objective of this project is to use this method to implement a joystick module, by which it will be possible to control remotely the robot by acting on an external joystick (to be set up and interfaced with the robot). Clearly, the two-dimensional command coming from the joystick must be appropriately mapped to a three-dimensional displacement. Implementation in Webots and then on the actual NAO robot.

**Literature**
NAO documentation
De Luca and Oriolo, "Local incremental planning for nonholonomic mobile robots," ICRA 1994

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## 6. A comparison of WMR control approaches for stop-and-go motions

**Synopsis**
Wheeled mobile robots are usually nonholonomic. One of the consequences of this fact is that they admit no universal controller; that is, no single controller exists that can provide stabilization of these systems to arbitrary trajectories, persistent or not persistent. Yet, many robot missions (e.g., exploration) require stop-and-go motions, and continuous switching between different control modes is undesirable. The objective of this project is to compare the performance in these situations of two alternative control approaches that do not require switching. A MATLAB implementation is recommended.

**Literature**
Freda and Oriolo, "Vision-based interception of a moving target with a nonholonomic mobile robot," Robotics and Autonomous Systems, vol. 55, pp. 419-432, 2007
Morin and Samson, "Control of nonholonomic mobile robots based on the transverse function approach," IEEE Transactions on Robotics, vol. 25, pp. 1058--1073, 2009

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## 7. 3D navigation for a quadrotor UAV

**Synopsis**
Consider a quadrotor UAV flying in an indoor environment. An obstacle avoidance capability is essential to avoid walls, fly through doors, and so on. The objective of this project is to develop a method based on 3D artificial potential fields for solving the problem of leading the quadrotor to a certain goal without colliding with the obstacles. Implementation in MATLAB is recommended.

**Literature**
Paul et al, "UAV Formation Flight using 3D Potential Field", 16th Mediterranean Conference on Control and Automation, 2008

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## 8. Task-constrained motion planning for a snake-like robot

**Synopsis**

Consider the problem of planning collision-free motions for redundant robots subject to task space constraints (e.g., moving a particular point of the robot along a given trajectory). Previous approaches to the solution are based on the idea of sampling and inverting the task constraint to build a roadmap of task-constrained configurations which are then connected by simple local paths; hence, task tracking is not enforced during the motion between samples. If the simple local planner is replaced by a motion generation scheme that guarantees continued satisfaction of such constraint, we obtain accurate execution of the desired task without increasing the size of the roadmap. The objective of this project is to apply this approach to plan the motion of a free-flying snake-like robot in a 3D environment. Implementation in Kite Lab.

**Literature**

Oriolo, Vendittelli, “A control-based approach to task-constrained motion planning,” IROS 2009

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## 9. Multi-robot navigation with connectivity maintenance

**Synopsis**

Consider a group of mobile robots that must reach an assigned collective goal in an unknown environment. During the navigation, the robots can exchange information (e.g., local maps etc) if they are sufficiently close and in mutual visibility. The objective of this project is to modify the previously proposed Sensor-based Random Graph exploration method to goal-based navigation, while simultaneously enforcing the connectivity maintenance constraint. Implementation in Webots or ROS.

**Literature**

Franchi et al, "The Sensor-based Random Graph method for cooperative robot exploration," IEEE/ASME Transactions on Mechatronics, vol. 14, no. 2, pp. 163-175, 2009