Available theses (October 2014)

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## MSc Theses at Politecnico di Milano

<table>
<thead>
<tr>
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<th>“Tesi”</th>
<th>“Tesina”</th>
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<tbody>
<tr>
<td><strong>Expected effort</strong></td>
<td>≈ 6 months full time</td>
<td>≈ 3÷4 months full time</td>
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<td><strong>Reviewer required</strong></td>
<td>yes</td>
<td>no</td>
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<tr>
<td><strong>Maximum increment for the final grade</strong></td>
<td>7/110</td>
<td>4/110</td>
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Areas for possible theses at MERLIN

- Industrial robotics
- Unmanned autonomous vehicles
- Mobile manipulation
- Aerial manipulation
- Robot simulators
- Flexible and continuum systems
Industrial robotics

What we want to study:

- Force control algorithms suitable for industrial technological applications
- Innovative control strategies for manual guidance in contact with a surface
- New algorithms for trajectory planning and optimization
- Safe human-robot interaction
Studying human-robot interaction during walk-through programming tasks

- Classical walk-through programming (manual guidance) techniques do not consider the effects of the interaction with the human.
- We want to develop human arm models suitable to study the human-robot interaction...
- …and study techniques to identify human arm parameters in order to adapt the robot impedance behavior.
- Application on the COMAU Smart Six robot.
Walk-through programming of robots in contact with a surface

- We have developed a methodology for manual guidance of robots
- The method has still some problems when in contact with the environment
- How can we design a manual guidance which can discriminate between programming forces and contact forces?
- Application on the COMAU Smart Six robot
Improving force control in industrial manipulators

- During a robotic operation like metal finishing or contour following, the robot exploits force measurements in order to track the workpiece profile and control the finishing quality.
- Can we design a high bandwidth force controller in spite of the mechanical resonances of the robot?
- Application on the COMAU Smart Six robot.
Developing an interface for constraint-based robot programming

- Real-time trajectory (re)planning is needed to make the robot reactive to external events
- We want to achieve best tracking of a reference trajectory subject to (event-based) constraints
- A programming interface with ABB industrial controller has to be developed, which allows commands like, e.g. “MoveJ safely”
- Application on the ABB IRB140 or ABB FRIDA
Safe and ergonomic co-manipulation of bulky objects

- Human-robot interaction has to be both safe and ergonomic
- Human safety and ergonomic comfort can be achieved constraining the robot handling pose
- This is seen as an application of constraint-based reactive trajectory generation
- Surveillance camera and human pose estimation are used
- Application on the ABB IRB140 or ABB FRIDA

Unsafe (occlusion)

Non ergonomic
Dynamically feasible path parameterization

- Algorithms for trajectory generation considering dynamic constraints have been available since late 80’s
- How to obtain real-time implementation?
- Online generation of dynamically feasible trajectories on an assigned path
- Application on the ABB IRB140

\[ B(q) \ddot{q} + h(q, \dot{q}) = \tau \]

\[ \tau_{min} \leq \tau \leq \tau_{max} \]
Multiple-target trajectory generation

- Trajectory generators implicitly assume a point target state of motion (position & velocity)
- Many applications allow some redundancy in the target state (e.g. grasping)
- This redundancy might be optimized (e.g. minimum time, minimum jerk, ...) while selecting the best target
- Application on the ABB IRB140 or ABB FRIDA

Example: cylindrical objects can be grasped from different position due to axial symmetry
Momentum monitoring for safe human-robot collaboration

- Momentum is a mechanical quantity that accounts for both mass and velocity.
- Thresholds for impact not inducing significant pain are available.
- How can we move the robot to enforce those constraints?
- Application on the ABB IRB140 or ABB FRIDA or on a KUKA LBR iiwa (to be confirmed).
We have studied natural exploitation of kinematic redundancy during in-hand manipulation.

Human-like redundancy resolution has been transferred to the robotic arms.

We want to apply these concepts to a significant dual arm assembly operation.

Application on ABB FRIDA.
Vision guided operations for assistive manipulators

- In industry systems are used that help workers move heavy loads alleviating effort
- These human extenders can be seen as manipulators with passive (not actuated) joints
- In some situations (for example when occlusions occur) use of vision sensor can be beneficial to assist the worker in the correct positioning of the load
- Application on the manipulators of a primary company
What we want to study:

- Developing dynamic models of vehicles
- Developing planning and control strategies for unmanned autonomous vehicles
Tilt control of narrow-track electric vehicles

- Developing techniques to measure and control the tilt of narrow-track vehicles, based on the use of tilting mechanisms
- The work will be carried out in the Modelica/Dymola modeling and simulation environment, taking into account the configuration of a real vehicle
Introducing kino-dynamic constraints in random sampling planners

- Path/trajectory planning is the first task to be accomplished to set up an autonomous vehicle
- To create feasible and safe paths, we must consider vehicle dynamic and kinematic characteristics
- We aim at developing a random sampling planner that takes into account vehicle kino-dynamic constraints
- Application to a Yamaha Grizzly ATV and to models of aerial vehicles
Introducing kino-dynamic constraints in search based planners

- Path/trajectory planning is the first task to be accomplished to set up an autonomous vehicle.
- To create feasible and safe paths, we must consider vehicle dynamic and kinematic characteristics.
- We aim at developing a search-based planner that takes into account vehicle kino-dynamic constraints.
- Application to a Yamaha Grizzly ATV and to models of aerial vehicles.
Comparing different path planners for autonomous vehicles

- There are at least three different path planning techniques: random sampling, search based, and model based planners.
- We want to define benchmark environments for outdoor autonomous vehicles to compare the different techniques...
- ...and compare at least two of them in different environments.
- Application to a Yamaha Grizzly ATV and to models of aerial vehicles.

“...eminently necessary since, by definition, a robot accomplishes tasks by moving in the real world.”

J.-C. Latombe (1991)
Control of autonomous vehicles for off-road applications

- Developing a control system for unmanned autonomous vehicles based on Model Predictive Control (MPC)
- The vehicle must follow a pre-planned path...
- …avoiding moving obstacles, and…
- …considering kino-dynamic constraints, e.g. roll-over, side slip, etc.
- Application to a Yamaha Grizzly ATV
Mobile manipulation

What we want to study:

- Dynamic modelling and control
- Sensor integration
- Recognition and grasping of moving objects
- Reactive navigation
Dynamic model and control of a KUKA youBot

- As for now, a kinematic model of the youBot mobile manipulator is used for control purposes.
- A dynamic model of the youBot base and arm system should be developed.
- Performance of dynamic model based controllers will be compared with the kinematic ones.
- Dymola dynamic simulator can also be used for early testing and tuning.

\[ \tau = M(\theta)\ddot{\theta} + C(\theta, \dot{\theta})\dot{\theta} + n(\theta). \]
Sensor integration for environment recognition

- A KUKA youBot equipped with different exteroceptive sensors is available.
- How to effectively fuse different sensors information and store data to build a map of the environment while the youBot is moving?
- How to re-use the acquired information when moving in already visited places?
- Which techniques should be used to track the robot position in the environment?
Trajectory generation for mobile manipulators tracking moving targets

- Recognition and tracking of objects must be implemented, using suitable exteroceptive sensors (Kinect, cameras, …)
- How to intercept the position of moving objects?
- Suitable constraints should be specified (e.g. to maintain the object in the field of view)
- A constraint-based control strategy can be used to incorporate predicted evolution of the objects motion into the end-effector trajectory generation
- Redundancy of the target position/orientation can be exploited (see also Thesis IR-7)
Combining human tracking with reactive navigation for mobile manipulators

- A system able to track and predict human walking motion has been developed.
- Predictive and reactive sensor-based control of a KUKA youBot has been designed and implemented.
- We want to integrate the tracking system with the youBot controller in order to allow both:
  - collision avoidance during execution of independent task
  - safe (physical) interaction during execution of cooperative tasks
A dynamic model of the youBot base and arm system should be developed.

Through available estimation algorithms, an external force/torque observer can be implemented to detect contact with the environment.

A constraint-based trajectory generation algorithm can provide both compliant behaviour and/or force control capabilities on top of estimated forces.

A mix of vision and contact information can be then used to perform an assembly task.

\[ \tau = M(\theta)\ddot{\theta} + C(\theta, \dot{\theta})\dot{\theta} + n(\theta). \]
Aerial manipulation

What we want to study:

- Control of a system composed of a quadrotor equipped with a robotic arm.
- Best use of the redundancy of an aerial manipulator
- Development of a first prototype
The goal is to control a system consisting of a quadrotor equipped with a robotic arm.

A critical aspect is the pose estimation of both quadrotor and arm end effector.

A vision based approach will be used, to be combined with IMU information and arm joints feedback.

Visual motions algorithms, sensors fusion, estimation process and control aspects will be addressed in the thesis.
The system composed by the quadrotor and the robotic arm should be able to manipulate objects and perform tasks.

In order to interact with environment, the different dynamics given by contact forces has to be considered, as long as the redundancy of the system has to be solved.

What are the best control strategy and approaching trajectory to perform a given task?
Algorithms for estimation, control and planning will be implemented and tested on a real platform.

The platform will comprise the mechanical structure as well as sensors and servomotors interfaces, wi-fi and wired communication.

The work will be split in a part of algorithm development and simulation (with a focus on estimation, control or trajectory planning) with a part of actual implementation of the system for the testbed, with a balance depending on the particular case.
What we want to study:

- comparing robot simulators
- virtualization of sensors in the simulation environment
There are many different robotic simulation environments

Some are focused on multi-body and multi-physics simulation, other on supporting world description and sensors simulation

What is the correct simulator for each problem?

Application to an industrial robotics or a mobile robotics scenario
Sensor virtualization in a simulation environment

- A simulation of our robotic cell environment has been developed using ROS and V-Rep, including robots, sensors and human workers.
- We want to design, deploy and test sensor fusion algorithms on the simulated environment.
- We want to investigate the possibility to use the virtual environment to perform fault detection and isolation with respect to real sensors.
- We want to investigate the possibility to use purely virtual sensors to improve our online tracking capabilities.
Flexible and continuum systems

What we want to study:

- Developing dynamic models of flexible devices
- Developing simplified models for controller design
- Developing control strategies for vibration damping
Model order reduction from finite element description

- Analysis and implementation of algorithms that, based on the description of the mass and stiffness matrices, and on the location of the nodes and elements of a finite element model, generate one or more reduced order models
- The analysis must be carried out in Matlab
- Application on various mechanical systems
Modelling and control of flexible and continuum robots

- Flexible and continuum robots require more advanced modelling and control techniques
- We want to develop models, experimentally validated, of existing continuum robots …
- and study the trajectory tracking controller, considering robot deformations/vibrations
- Application to models of flexible robots (experimental data available for validation)
Shimmy is a bicycle (or motorcycle) dynamic instability involving oscillations of the steering assembly at frequencies too high for pilot reaction.

Shimmy may unexpectedly arise at high speed and may be frightening and dangerous.

Despite the efforts of many researchers the conditions (bicycle geometry, stiffness and compliances, rider behaviour, ...) causing the onset of shimmy are not known.

Investigating such conditions is the aim of the thesis, based on experimental data, kinematics and dynamics model, and nonlinear dynamics analysis tools.