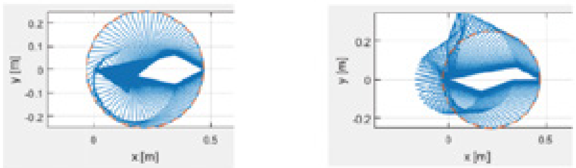
Optimal motion planning of redundant robot manipulators

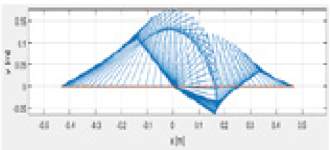
Increasing energy prices and growing environmental awareness have driven engineers and scientists to find new solutions for reducing energy consumption in robotic manufacturing. In addition, the spread of 7-DOF collaborative robots in industry gives a real chance to minimize the required mechanical energy and related costs by exploiting their redundancy through new motion planning methods.
The aim of this research line is to develop new motion planning methods for minimizing the energy consumption of redundant robot manipulators, with a focus on trajectory tracking tasks. Typical economically important industrial applications are for example robotic painting, sand blasting, and machining.
The proposed research line is split in the following interconnected research topics:

1) Energy-efficient motion through prediction of minimum energy direction: ***totally new solution developed, suitable for real-time implementation, based on a predictive kinematic control algorithm that computes the direction of minimum end-effector error and kinetic energy integral over a set of future exploration points.***



Stroboscopic views of robot motion: preliminary investigations showed 33% energy savings of proposed algorithm (left) wrt minimum velocities solution (right) for a circular robot trajectory.

2) Global optimum method: ***the proposed method is based on the generation of a set of convenient robot trajectories to be used as input for a multi start algorithm, which significantly reduces the complexity and computational burden of optimal control and genetic algorithms. The method is developed for minimizing kinetic energy, but can be extended for a generic cost function.***



Preliminary investigations showed up to 57% energy savings wrt pseudoinverse solution using a free robot initial configuration (top). Validation will be carried out in real industrial test cases using the latest generation collaborative robots (right).

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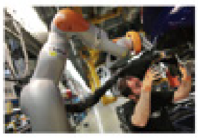

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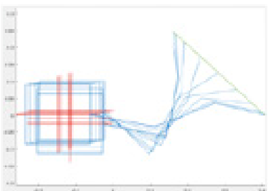
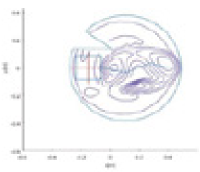
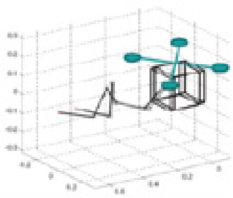
3) Extended reactionless workspace of a free-flying robot: ***the zero-reaction workspace of a redundant manipulator mounted on a moving base is significantly extended through the use of a reaction wheel. Zero reactions on the base correspond to minimum energy consumption to stabilize the moving base and increased autonomy.***



Stroboscopic view of robot motion (with reaction wheel).



Extended reactionless workspace with iso-manipulability curves.



LTU Aerobot. Potential applications/validation scenarios:
- Service robotics (e.g. search and rescue, extreme environment, etc.)
- Industry (assembly, logistics, etc.)

Robotica e Industria 4.0

Robotics and Industry 4.0

DII research group

Machine Mechanics

Silvio Cocuzza
silvio.cocuzza@unipd.it
Phone: +39 049 8276813

www.dii.unipd.it

The research activity is carried out in collaboration with University of Strathclyde, Glasgow (UK)

Main research topics:
- Redundancy and optimization in robotics
- Global vs local optimization
- Energy-efficient motion planning
- Trajectory optimization
- Kinematic control
- Reaction control
- Robot workspace analysis
- Manipulability analysis
- Industry 4.0
- Collaborative robots
- Aerial manipulators