Real-time trajectory planning for human-friendly collaborative robotics

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Real-Time Trajectory Planning for Human-Friendly Collaborative Robotics

By

Matteo Melchiorre

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Supervisor(s):
Prof. Stefano Mauro, Supervisor
Prof. Stefano Pastorelli, Co-Supervisor

Doctoral Examination Committee:
Prof. Benedetto Allotta, Referee, Università degli Studi di Firenze
Prof. Francesco Braghin, Referee, Politecnico di Milano

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Abstract

Collaborative robotics identifies human-robot collaboration in the industrial field. It is realized by removing physical fences between human workers and robotic systems in favor of a shared workspace. In this way, human and robot can work side by side to accomplish a task.

Robots designed for this type of application are called "collaborative robots" and are mostly in the form of anthropomorphic manipulators. For a safe and effective collaboration, collaborative robots must respond in real-time to the operator's movements. This work describes a solution based on 3D vision systems and novel algorithms for real-time trajectory planning, specifically designed for the highest level of collaboration. Two possible applications are described: collision avoidance and hand-over.

Collision avoidance algorithms allow the robot to avoid obstacles (objects or the human operator) so that the trajectories are safe and ergonomic. This work presents two collision avoidance algorithms. One has minor improvements with respect to the state of the art. It drives the entire robot body away from obstacles using repulsive actions, expressed in terms of repulsive velocities. The other is a major contribution to the current state of knowledge. It exploits artificial potential fields with multiple attractors to obtain a controlled collision-free motion of the end effector.

Hand-over algorithms allow the bidirectional exchange of objects between operator and robot. A reactive hand-over is obtained by driving the robot towards the human hand, which can give or receive objects in any point of the robot workspace. This work describes an improved algorithm that combine results of previous works with a predictive scheme to anticipate human hand motion. The method also considers ergonomics and is designed to orient the robot tool according to the upper limb of the worker.

Each algorithm uses robot and human position data to calculate robot commands in terms of joint velocities. The actual configuration of the robot is obtained by direct kinematics from feedback signals. Human motion is tracked by

a 3D vision system based on multiple Microsoft Kinect cameras. Sensor fusion techniques are implemented to optimize human position data by means of skeleton as well as point cloud.

Depending on the grade of novelty, the developed algorithms are verified either by simulation or experimental test. The simulation environment is built in Matlab, considering a kinematic model of the collaborative robot. The experimental tests are carried out with a robotic cell composed of a collaborative robot UR3 from Universal Robots and the 3D vision system. The results show collision avoidance and hand-over algorithms performances in different scenarios.

A real-world application of collision avoidance based on repulsive velocities is presented. The experimental test with the robotic cell proves that the method can safely drive an assembly task. The robot collects the parts to be mounted while the human prepares the assembly. The operator can access anytime the robot workspace. His position is monitored with skeleton tracking. If the distance from the robot is within a defined threshold, the robot reacts with collision-free trajectories. Compared to the lowest level of collaboration, where the robot stops to prevent hazards, the proposed system optimizes productivity by saving up to the 18% of the cycle time.

Collision avoidance based on repulsive velocities is also tested with human point cloud instead of skeleton. Simulation results show that the methodology is effective and produces safe robot trajectories. However, the experimental test indicates some limitations due to the large amount of data to be processed in real-time.

Collision avoidance based on artificial potential fields with multiple attractors is verified in the simulation environment and validated with the real robot. The obstacles are combined with local attractors opportunely placed to influence the robot collision-free trajectory along preferred direction. Results show that the end-effector avoid obstacles choosing the side of the local attractor. This can be used to control the robot behavior when dealing with obstacles, so that trajectories can be predicted by the operator.

A hand-over task is tested with the robotic cell. The improved hand-over algorithm can quickly adjust the robot pose according to the human forearm. The prediction scheme ensures a more natural hand-over by reducing the waiting time of the operator.