Obstacle Detection and Tracking for Safe Human-Robot Interaction Based on Multi-Sensory Point Clouds

Angelika Fetzner, Christian Frese, Christian Frey

I. Introduction

For close human-robot interaction without physical separation, safety has to be ensured by monitoring the humans while they are within the robot workspace. Here we discuss the problem of selecting and placing a suitable set of sensors for mobile manipulators. Furthermore, methods for detection and tracking of dynamic obstacles based on data from heterogeneous sensors are presented. The approach is validated by experimental results on real sensor data acquired by the robot.

II. Sensor setup and placement

For the workspace monitoring task in human-robot interaction on- and off-board sensors are conceivable which enable the robot to perceive its environment. With regard to planning of collision free trajectories and collision avoidance, the appliance of depth sensors is most suitable, as the measured information directly delivers 3D points of the environment.

The sensors can be placed on the robot or can be installed in the workcell. As the number of insertable sensors is restricted due to purchase costs, energy consumption (especially on mobile robots), and the required computing capacity, the sensor selection and placement is a non-trivial task. According to [3], a good coverage is achieved if the sensors are placed high in the corners of the workcell. But this solution is restricted to stationary robot arms and mobile robots in small limited workcells. Therefore, the sensors are mounted on the mobile platform to achieve a solution independent of the workcell size.

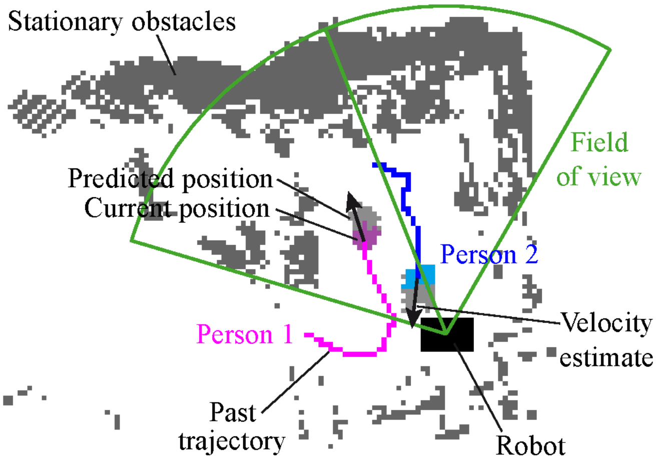
Currently, the sensors are heuristically placed based on expert knowledge and the placement is evaluated by means of sensor simulation. Simulated sensor data allows for visualising the monitored sections of the robot environment without a real hardware setup. Based on ray cast methods, the environment in the sensors' field of view is subdivided into free, occupied and occluded space. Using this approach, sets of different sensors can be analysed to find occlusions during a test run of the use case.

III. Obstacle detection and tracking

Based on the information obtained from multiple heterogeneous sensors, detection and tracking of humans and other moving obstacles is performed.

This work has been funded by the European Commission's 7th Framework Programme as part of the project SAPHARI under grant agreement ICT-287513.

The authors are with Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB, Fraunhoferstr. 1, 76131 Karlsruhe, Germany, {firstname.lastname}@iosb.fraunhofer.de



As a common representation of the planar environment in order to fuse data acquired by heterogeneous sensors, a 2D grid cell structure is established [1], [2]. Features such as the number of points within the grid cell, the height of the measured points, and the type of the detecting sensor are stored as attributes of the grid cell.

Data association is achieved by defining a distance function for object descriptors which basically rates the differences in position and other features with suitable weighting factors. For each object, a Kalman filter is set up. The robot's ego-motion is compensated before applying the position update to the Kalman filter. Future obstacle positions predicted by the Kalman filter can be checked against the planned trajectory of the robot in order to prevent collisions.

The proposed method has been applied to real data acquired by two 2D laser scanners and two triangulation-based depth cameras on the robot. The laser scanners cover a planar 360° field of view around the mobile robot, while the depth cameras monitor the 3D space next to the manipulator. The figure shows an example of tracking two walking humans in a laboratory environment, which is quite cluttered with stationary obstacles like tables, chairs, fences, etc. The humans are continuously tracked while they are moving between the fields of view of the different sensors.

References

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