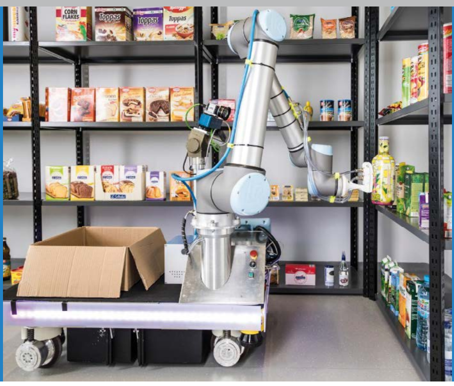
Fraunhofer

IPA

FRAUNHOFER INSTITUTE FOR MANUFACTURING ENGINEERING AND AUTOMATION IPA


1


2


3

1 *rob@work fetching articles in a supermarket.*
2 *Robotic home assistant Care-O-bot® 4 preparing some food.*
3 *Autonomous excavator for moving barrels.*

COLLISION-FREE MANIPULATION FOR MOBILE SERVICE ROBOTS IN DYNAMIC ENVIRONMENTS

Background

Mobile service robots with manipulation abilities are gradually starting to be used in our everyday environments. In contrast to industrial robots with their fixed safety installations, the environment of a service robot is significantly more complex. In particular, the robot has to ensure that it does not pose a risk to humans or their surroundings at any time. To achieve this, the robot system must react appropriately and, above all, quickly to any changes in its environment.

Further challenges arise in cases where the movement of mobile platforms and manipulator(s) need to be synchronized. This may be necessary in especially challenging tasks or in order to avoid obstacles in confined spaces.

Our solution

Fraunhofer IPA has many years of experience in the field of manipulation with mobile service robots. Our flexible software framework unites basic algorithms for kinematic calculations with different methods for grasp planning, motion planning and motion control. Our solutions ensure that the robot's motions are always smooth – even in the presence of dynamic collision objects.

The software framework also includes intelligent control methods for the synchronized and coordinated motion of two or more actuators, e.g. two robotic arms or a robotic arm with a mobile base.

Fraunhofer Institute for Manufacturing Engineering and Automation IPA

Nobelstrasse 12
70569 Stuttgart, Germany

Contact
Mayank Patel
Phone +49 711 970-1879
mayank.patel@ipa.fraunhofer.de

Mostafa Aboubakr
Phone +49 711 970-1956
mostafa.aboubakr@ipa.fraunhofer.de

www.ipa.fraunhofer.de/en/robotsystems

System architecture

Mobile manipulation tasks can be separated into motion planning and motion control functions. Motion planning includes grasp planning and trajectory planning, which use the robot and environment model, as well as object detection results for example, as an input. The geometry of an object is utilized to calculate suitable grasp configurations. The motion control module either uses a sequence of motions or the desired end-effector location as an input. The motion planner, as well as the motion controller, incorporate collision detection, e.g. based on processing 3D depth images, thus ensuring a collision-free movement.

All modules come with ROS (Robot Operating System) interfaces, which enable simple integration with other software modules to facilitate application development.

Grasp planning

The grasp planning module features methods for either the model-based or model-free grasping of objects. For the model-based solution, the CAD model or other 3D models suitable for detecting the object are required. Based on the models, the object is localized and a collision-free path calculated to grasp the object. For model-free grasping, our software can calculate suitable grasping configurations and feasible grasping strategies directly from a 3D point cloud. The two grasping solutions enable the user to choose the best grasp planning module for his application.

Trajectory planning

Our software framework provides a generic and flexible solution for planning movements with mobile manipulators. The software can be easily adapted to various manipulation tasks. The module provides different search-based or optimized-based motion planners. It computes a sequence of motions in the preferred direction either in Cartesian space or joint space. It is able to incorporate collision avoidance and consider restrictions in joint movement. The trajectory planning module is also capable of calculating collision-free simultaneous motions for dual-arm robots.

Motion control

Our motion controller is based on the method of Nonlinear Model Predictive Control (NMPC). It takes inputs from the motion planning module, which are either a sequence of motions or the desired target location. It continuously tracks real-time information about the trajectory and (predicted) obstacle location. An exponential cost function is used to reliably avoid collisions while considering relevant joint restrictions. As a result, continuous positions or velocities in the joint/Cartesian space are generated, allowing the robot to perform a smooth reactive movement without abrupt stops. The module also prevents the robot from colliding with itself.

The developed method is generic, thus enabling it to be easily adapted to different types of robotic arms, as well as for redundant manipulators or the complete kinematic chain of a mobile manipulation robot.

Potential application areas

Retail and logistics

Service robots use collision free manipulation combined with our object detection software in order to perform pick-and-place tasks such as grasping objects from the shelves of supermarkets and warehouses. Functionalities available in the software library make it possible to operate the robotic arm safely even in the presence of humans.

Household assistance

In the future, service robots will be able to help humans with everyday household tasks. In order to operate in confined spaces, platform and arm movements must be efficiently coordinated, for example to open doors. Orientation constraints also have to be considered, e.g. when handling cups or open bottles.

Our services

Fraunhofer IPA assists you in all the development phases of your service robot application:

- Advice in connection with complex mobile manipulators tasks, particularly with selecting the best suited hardware for an individual task and full body kinematics.
- Implementation of the manipulation software for your robot system: we integrate individual modules into existing software or develop customized new components.
- Design and realization of application scenarios including machine vision or navigation functions.