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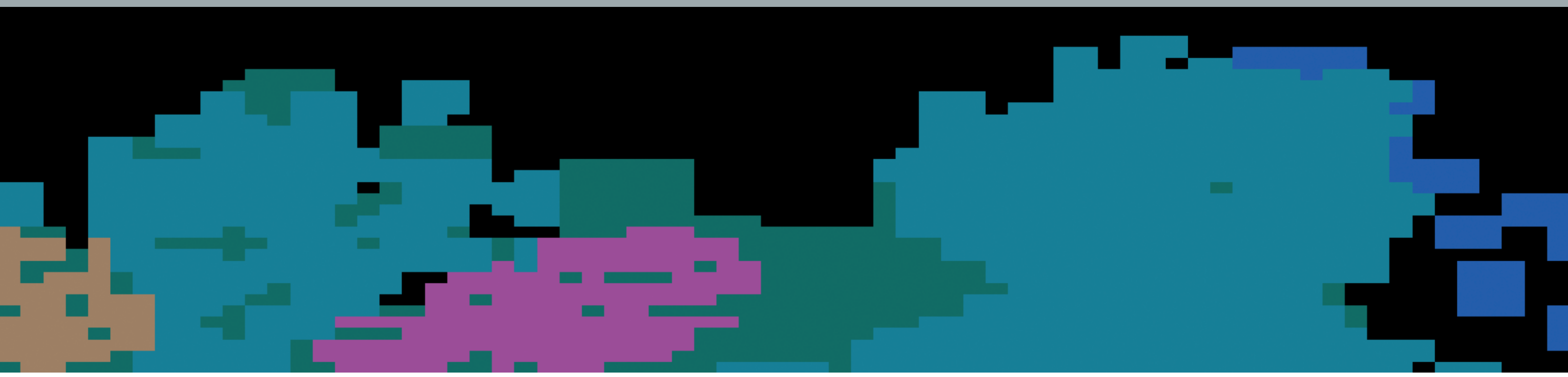

SAFE MANIPULATION FOR MOBILE SERVICE ROBOTS IN DYNAMIC ENVIRONMENTS

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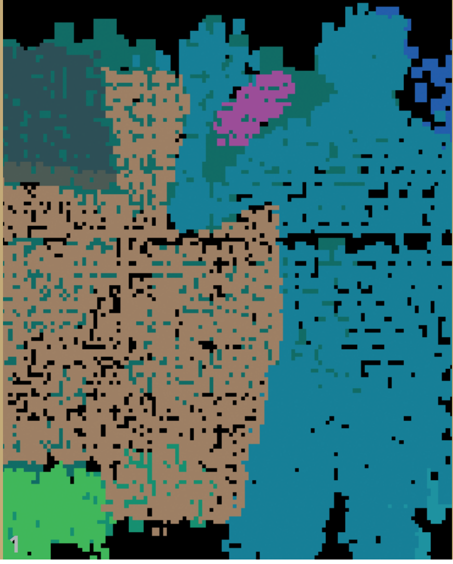
Starting Point

Autonomous service robots are increasingly finding their way into our daily lives. Future service robot products must be capable of executing manipulation operations without collisions, also in dynamic environments. Collision monitoring includes both self-collisions of the robot and also collisions with the robot's environment. Industrial robots are usually so designed that the individual joints cannot collide with each other, which means that self-collision avoidance is not required. However, light-weight arms with more than six degrees of freedom are often used especially for mobile robots. Furthermore, many mobile robots have several manipulators (e.g. for movable sensor carriers etc.), in which case self-collision monitoring becomes indispensable.

The various methods of collision avoidance can be broken down into offline methods, such as path planning, and online methods, which continuously run in the background while the manipulators are moving. For dynamic environments, only online methods are capable of offering sufficient safety with regard to freedom from collision with external objects.

Fraunhofer IPA has developed a controller for the manipulator of mobile service robots which is capable of in-dependently planning and executing manipulation operations for arms with different kinematics, but which can also respond in real-time to dynamic changes in environment and thereby avoid collisions. Where the arm is mounted on a mobile platform, the controller can also execute cross-functional planning of coordinated arm/platform movements.



Modelling of the Robot and its Environment

The entire robot setup is modelled using »oriented bounding boxes« (OBBs), with a distinction being made between static components (e.g. the robot's basis) and dynamic components (e. g. its manipulators). The dynamic components are mapped by socalled articulated models which are updated with each robot movement according to the current angles of the joints, each joint being mapped as an individual OBB. Collision detection algorithms can be performed based on this model.

The environment is modelled using a 3D time-of-flight sensor which delivers distance values of the environment at around 20 Hz in the form of a 3D point cloud. A voxelization process is used to generate a 3D obstacle model from this point cloud.

Dynamic Path Planning

Initially, a so called roadmap is generated offline, which contains about 30.000 different manipulator configurations distributed over the total workspace of the robot arm. For each of these configurations, represented by nodes in the roadmap, and respective transitions, represented by vertices in the roadmap, collision checking is performed and colliding configurations and transitions are deactivated. The roadmap thus already provides collision free paths between the corresponding arm configurations in an obstacle free environment. In order to be able to generate collision free paths in an environment with moving obstacles, a second processing step is required: All nodes and vertices in the roadmap are mapped to a 3D occupancy grid. As this mapping is independent of the current environment, this step can also be performed offline.

In a third step, the 3D obstacle model can be mapped to the 3D occupancy grid and thus to the roadmap, deactivating all nodes and vertices that are blocked by obstacles. A standard shortest path algorithm can now be applied to the modified roadmap to get a collision free path for the current environment. As the computationally intensive collision checking operations are performed offline (except for checking the connection of the start and goal configuration to the roadmap), the collision free path search can be conducted online.

Coordinated Arm/Platform Movement

Mobile service robots are often equipped with compact and light-weight robot arms whose manipulation workspaces are rather small. The mobile base of the robot can here be used to enhance the manipulation workspace in a way that also complex operations such as opening a door can be performed. Therefore, the manipulator controller is equipped with a fast feed-forward port, which enables its combination with various platform kinematics, that are in turn controlled by separate software components. The optimal use of real-time technology like Xenomai and RT-Net in addition enables synchronous control of arm and platform movements. This connection in addition enables to support the movements of the manipulator by the localisation and sensors of the mobile base.

What we offer

Fraunhofer IPA will assist you in all phases of development of your service robot application. More particularly, we offer you:

- Advice in the design of mobile service robots, especially in relation to the selection of the manipulator hardware
- Integration of the complete arm control including kinematics, collision avoidance, path planning, coordinated arm/platform movement for redundant robot hardware
- Integration of individual modules into existing controls
- Customized development of new components for your control

Contact us to discuss your personal application scenario.

1 *3D obstacle model*
2 *Dynamic path planning*
3 *Force controlled manipulation of a hand wheel*