

SAFE NAVIGATION OF AUTONOMOUS SYSTEMS IN DYNAMIC ENVIRONMENTS

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Starting Point

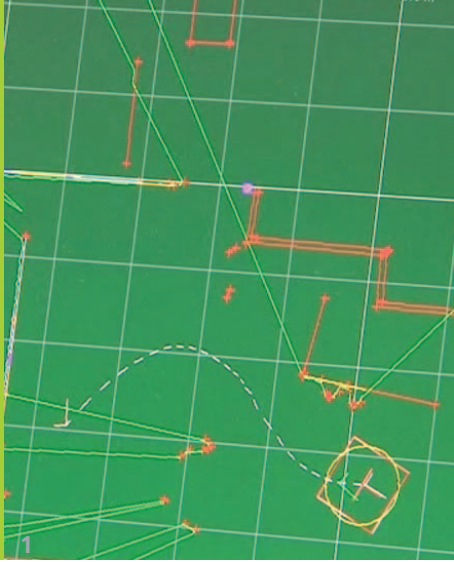
With the growth of automation, the working spaces of humans and machines are coming closer and closer together. This is especially true of autonomous mobile systems such as autonomous guided vehicles and mobile service robots, which in some cases already today occupy one and the same working space with humans. This trend increases the demands on the navigation of mobile systems. On the one hand, proximity to humans calls for a high degree of safety and reliability on the part of the navigation system. On the other hand, the systems must be capable of responding flexibly to changes in their environment.

Fraunhofer IPA has many years of experience in the development of software for the navigation of autonomous systems. The hitherto realized software modules

have been used in a wide variety of different applications and environments both in industry and also in the public sector and have demonstrated their reliability, over several years of continuous operation. The existing modules include, in particular, components for mapping and localization in natural environments, path planning and path optimization in dynamic environments as well as for the control of a variety of vehicle kinematics.

Mapping and Localization

The localization of an autonomous system is based on two principles. Firstly, the current position and orientation of the vehicle is estimated by dead reckoning and mathematical integration of the travelled route. Where exclusive use is made of odometric information, however, small errors are unavoidable and these add up over time.



Therefore, additional use is made of environment sensors, such as laser scanners, ultrasound sensors and cameras, in order to detect a variety of environment features. These features are checked against their reference positions, which are stored on the vehicle. Finally, the position of the vehicle is calculated in relation to the detected environment features.

The environment map required for localization can be generated from existing CAD data. Alternatively, it can be independently learned by the autonomous system by means of a SLAM process, which involves the system exploring its environment and recording all the detected environment features in its environment map.

Path Planning and Path Optimization

Path planning means determining a suitable trajectory for the movement of the vehicle. Depending on the particular application, path planning will be either target-point-based (e.g. for transport tasks) or area-coverage (e.g. for cleaning a floor).

In target-point-based planning, a distance- or time-optimized trajectory is calculated between a starting configuration and a target configuration. Area-coverage planning computes a path that allows complete coverage of the treated area with little overlap. In either case, the previously learned environment map is used as the basis for planning. The path planning takes into consideration the geometry and kinematics of the vehicle and optimizes the path

accordingly. This means that, given a suitable design of the vehicle, it is possible to safely negotiate even extremely narrow passages. Depending on the vehicle's operating environment, it is possible to choose between different path planning approaches.

Path optimization takes account not only of the environment map, but also of information from sensors. This makes it possible to adapt the path to changing parameters, e.g. if a point on the planned path is inaccessible because of a dynamic obstacle, such as a person or piece of furniture. For this purpose, use is made of the »elastic bands« method, in which the path is modelled as a rubber band that is wound around detected obstacles and smoothed.

Undercarriage Control

The undercarriage controller guarantees that the desired robot velocities are achieved in a smooth and efficient manner. The configuration space of the robot is represented by the instantaneous centre of rotation in spherical coordinates. Using this representation it is possible to provide a unified interface on velocity level even for vehicles with different kinematics.

For simple kinematics such as differential drives the actuator set points can be calculated directly from the velocity set points. Yet, for more complex, e.g. pseudo-omnidirectional, vehicles precise coordination of the different actuators is required. Therefore, an additional control cascade has

been integrated. This additional controller uses a potential field approach to avoid singular configurations and thus reduces the complexity higher level planners have to cope with.

What we offer

Fraunhofer IPA will help you in all phases of development of your customized navigation software:

- Advice in the design and selection of navigation methods
- Licensing/development of individual navigation modules to suit your specific application
- Integration of new navigation modules into existing vehicle controls
- Customized development of your complete vehicle control

Contact us to discuss your personal application scenario.

1 *Planning a collision free path to a target*

2 *Home assistant »Care-O-bot® 3« navigating safely among humans*

3 *Application of the navigation system on an omnidirectional transport platform*