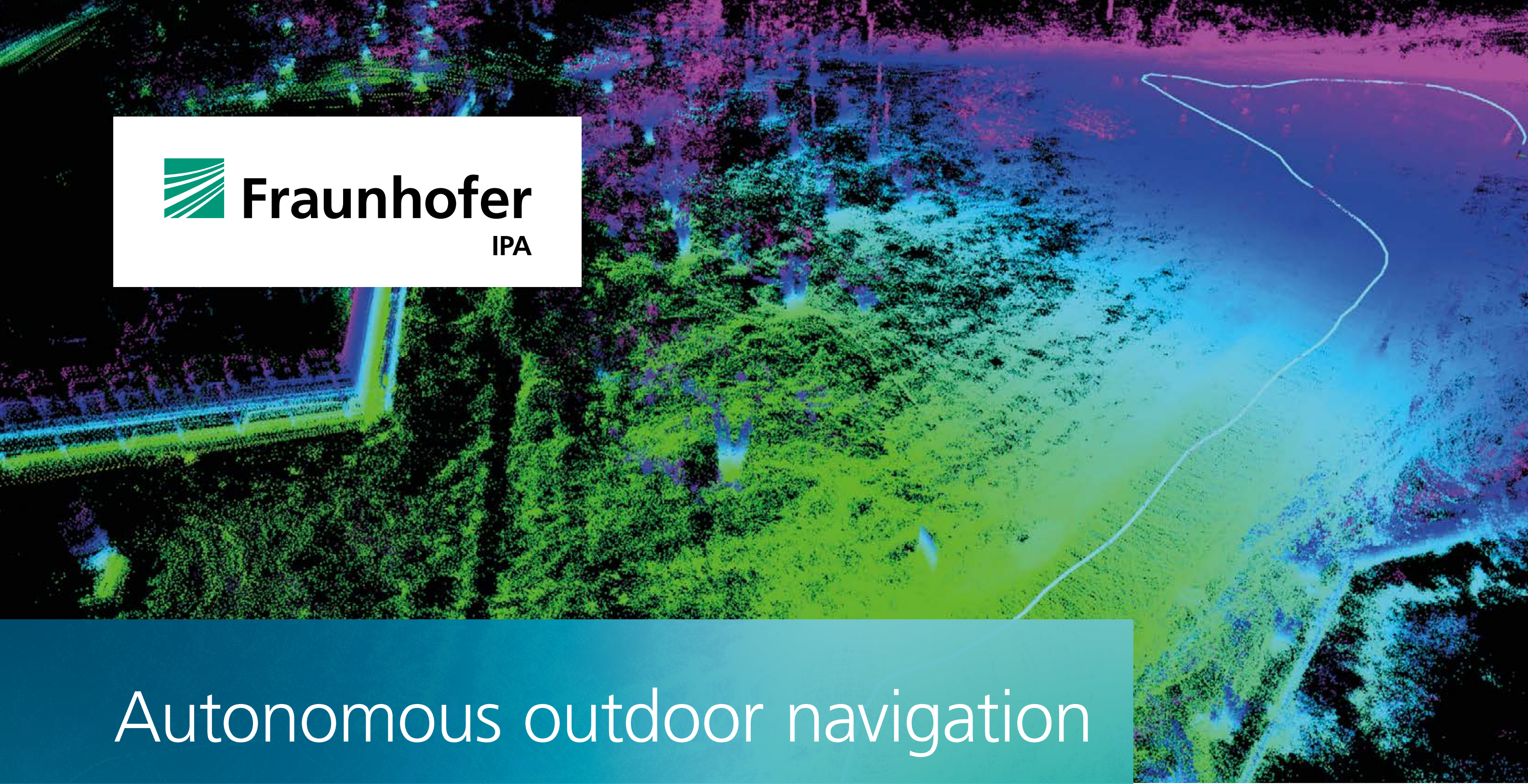


Autonomous outdoor navigation

Autonomy for machines in agriculture

3D LiDAR SLAM outdoors. The robot's paths can be seen, as well as features such as trees and house walls in the point cloud.
Source: Fraunhofer IPA

The research group "Professional Service Robots – Outdoor" at Fraunhofer IPA develops autonomous outdoor robots for complex application scenarios. The navigation software CURTos forms the basis for full autonomy.

Challenges and objectives of autonomy

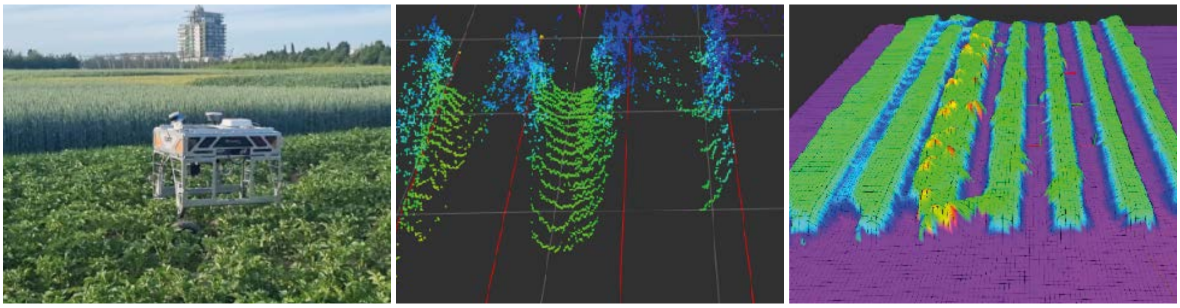
Enabling robots or work machines to move autonomously is a multi-stage process. In order for vehicles to navigate reliably and efficiently, the environment must be precisely modeled. This is essential for localization, as outdoor areas pose particular challenges, such as varying slip behavior between the vehicle and the ground. Furthermore, environment models serve as a basis for decision-making processes, especially those concerning path planning. The complex environment in outdoor areas cannot be captured by a single sensor; instead, the data from several sensors must be merged and interpreted. The diversity and sometimes high dynamics of the navigable and non-navigable structures in the environment further complicate this process. Examples include uneven terrain, vegetation, different surfaces, and varying weather conditions. In addition, dirt such as mud, dust swirls or organic substances hamper the measurements of imaging sensor equipment such as LiDAR and cameras.

CURTos

Thanks to the CURTos navigation software, a modular system is created that enables machines and robots to move around fully autonomously. To this end, CURTos can reliably detect and interpret the working environments of the robots outdoors, ensure precise localization in the environment and plan optimal paths for the respective application.

The navigation software is primarily based on sensor data from 3D LiDAR, RGB-D cameras and inertial sensors, but also supports further data from wheel encoders and GNSS, provided that high-quality measurements are available. However, this is not possible in many applications due to slippage or shielding. The navigation software therefore prefers reliable sensor data and uses technologies such as visual odometry and LiDAR inertial odometry for localization, depending on the application in question.

In environments with few features, such as the uncultivated areas in a field (l.), visual odometry (r.) can be used for localization with the help of deep learning approaches.
Source: Fraunhofer IPA



Localization of CURTdiff (l.) based on field row detection recognizable by red lines representing the extracted crop crests in point clouds (m.) and generation of elevation maps for geometric navigability analysis (r.).
Source: Fraunhofer IPA

Artificial intelligence (AI) is used to derive a comprehensive map of the environment from the sensor data, which forms the basis for the path planning algorithm. This enables the navigation software not only to avoid static and dynamic obstacles, but also to find optimal routes through environments containing obstacles that can be driven over, such as inclines or rough terrain.

Depending on the application, additional software modules can be developed and integrated. For example, a localization and planning module for crop rows was developed for use in arable farming, which makes it possible to cultivate fields completely autonomously with precise row tracking and autonomous turning maneuvers.

Further functions such as the recognition of human gestures or follow-me functions have been successfully integrated, which can increase the efficiency and user experience of the system.

Your advantages

CURTos users and developers receive a modular and adaptive navigation solution that enables mobile machines and robots to move autonomously. Customers can integrate the core modules of CURTos directly and then adapt them to the respective application. As a result, joint developments between Fraunhofer IPA and industrial customers can be implemented in a time- and cost-efficient manner. Examples of application in agriculture include

- Use of the navigation software
  - in field machines
  - in automatic feeders in stables
- Use of modules for field row detection by harvesting machines
- Development of prototypes with CURTos and the robot models CURTmini/CURTdiff
  - Construction industry
  - Permanent crops in agriculture

Our services

Fraunhofer IPA is your consultant, development partner and technology supplier for all aspects of mobile robot navigation. Our range of services includes:

- Workshops and seminars for employee training
- Execution of market, profitability and feasibility studies
- Development services from the first prototype to the system in productive use:
  - Conception and realization of service robots for the aforementioned application areas
  - Conception and realization of sub-technologies for autonomous machines
  - Autonomy for existing machines, robots or new prototypes (see Autonomy in 3 steps)
- Adaptation and further development of existing machines and systems

Autonomy in 3 steps

1. **ROSification**: The Robot Operating System (ROS) is open-source middleware for robotics and the de facto de facto standard in industry and research. It forms the basis for all further robotics software developments, e.g. driver developments for sensors and actuators, low-level machine control.
2. **Integration**: Once equipped with the ROS framework, you can integrate our in-house navigation solutions and, if required, third-party or open source modules in your machine.
3. **Adaption**: Depending on the application, navigation packages must be adapted or developed additionally. To achieve this, we work together with you, drawing on the experience of our broad user base.

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