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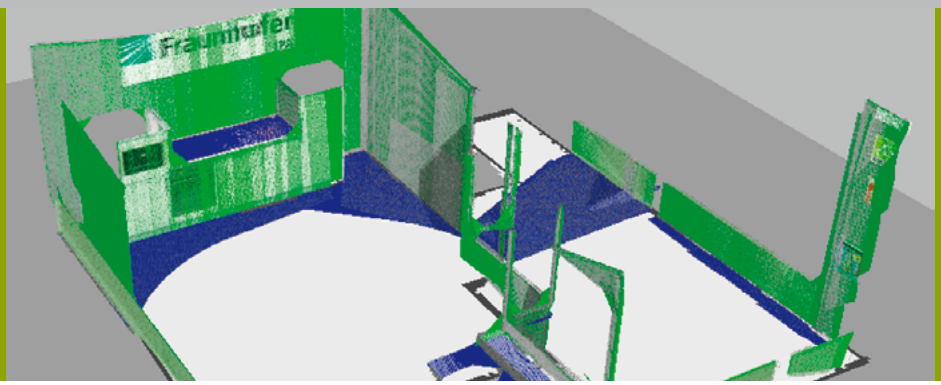

1 *3D environment map with plane segmentation.*

3D ENVIRONMENT RECONSTRUCTION AND INTERPRETATION FOR SERVICE ROBOTS

Background

Before a mobile service robot can fully autonomously execute manipulation and navigation tasks not only in known, but also in unknown and variable environments, the robot must be capable of sensing its environment in 3D. This calls for systematic and efficient detection of both stationary and dynamic objects.

Also for the teleoperation of robots, an intuitive user interface is dependent on the environment being sensed in a manner that is readily comprehensible to humans.

All such areas of application require not only environment reconstruction in virtual real-time but also robustness to variable light conditions and velocities.

Our solution

Fraunhofer IPA has developed a versatile software library for generation of 3D environment maps. This reconstructs a mobile robot's environment – including obstacles and objects that might obstruct the robot's 3D motions. The library includes the following functions:

Filtering and fusion of sensor data
First, the sensor data, such as the images from a colour camera and the depth data from a time-of-flight camera, is fused to generate a coloured point cloud in which each 3D point can be assigned a colour value. This point cloud can be used to subsequently extract features or for direct visualization of the environment.

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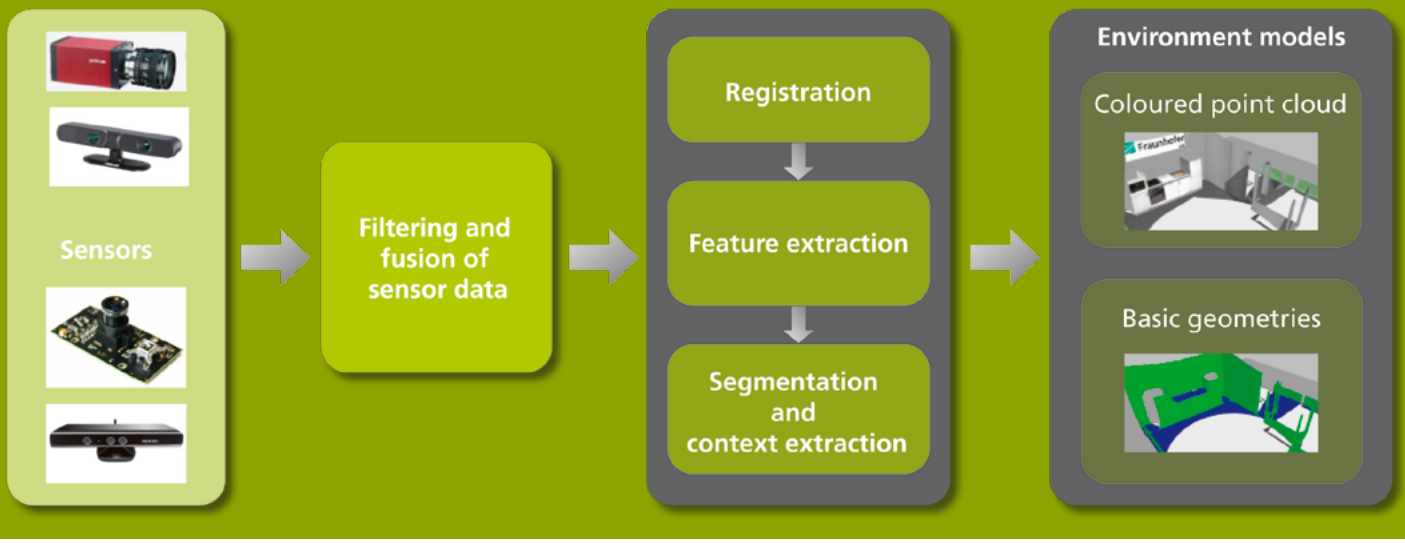

2

As the depth data is very noisy, it must be filtered. This is accomplished using a combination of various filter techniques to remove, for example, Gaussian noise or trailing edges.

Registration
While the robot is moving in a forward direction, successively sensed data must be fused in a logically coherent environment map. The purpose of registration is to balance out, ideally in real-time, any minor errors in sensor data measurement or in the estimated position of the robot.

Feature extraction
Feature extraction is the key step of data reduction necessary for environment reconstruction. The goal is to analyse the previously acquired 3D points in order to detect and extract those significant features that describe the geometrical environment. These features are combined with the 2D colour data, which can therefore also be used as feature points. The identified features are subsequently used to segment the environment into different zones.

Segmentation
Segmentation is both a key step in data reduction and also an important input factor for context extraction. Euclidean clusters or other techniques are employed in order to identify and distinguish individual areas and planes as well as geometrical shapes in the colour point cloud and thereby to describe the environment. The end result is a geometrical model of the robot's environment.

Context extraction
The results of point cloud segmentation can be used in an additional step as input for the extraction of semantic information. Various techniques and database information are employed to identify specific patterns – and therefore objects and environments – by means of probability calculations.

For example, geometrical relationships between the different shapes can serve as units of measure. For instance, it can normally be assumed that a table will consist of a horizontal table top and four cylinders (table legs). Ultimately, a semantic environment map is generated on the basis of this information.

Reference projects

Shadow Robotic System for Independent Living (SRS)
The goal of this project was to provide a teleoperated robot for enabling elderly citizens to live longer in their own homes. Environment reconstruction was used not only for collision-free navigation and manipulation but also for visualization on the part of the teleoperator.

Automation in logistics and manufacturing
One of the special challenges in the automated handling of products is the dynamic of the environment like displaced shelves or obstacles within the travel path. By comparison of the target state with the automatically reconstructed current state of the environment it is possible to detect those changes which are included in the further planning.

Efficient Installation Monitoring (ATLAS)
This projects integrated mobile robots as assistance systems directly into the process control of industrial installations. Interactive visualization techniques and automatically interpretable 3D environment models allowed efficient representation of installation, process and robot data.

What we offer

As your experienced partner, Fraunhofer IPA will support you in all phases of development of your customized software components for environment sensing:

- System design and selection of suitable sensors for environment reconstruction
- Customization of existing or development of new image processing techniques to meet your specific requirements
- Integration of techniques into your service robot application

2 *System architecture for 3D environment reconstruction.*