

ADAPTIVE 3D OBJECT RECOGNITION FOR SERVICE ROBOTS

Fraunhofer Institute for Manufacturing Engineering and Automation IPA

Nobelstrasse 12
70569 Stuttgart | Germany

Contact
Dipl.-Inf. Jan Fischer
Phone +49 711 970-1191
jan.fischer@ipa.fraunhofer.de

M.Eng. Jens Kubacki
Phone +49 711 970-1043
jens.kubacki@ipa.fraunhofer.de

www.ipa.fraunhofer.de

Starting Point

For the autonomous execution of handling tasks in variable everyday environments, a service robot must be capable of detecting objects in 3D and computing their precise position and orientation. The great diversity of environments and objects means that the models of all relevant objects can never be available. In the interests of maximum flexibility and expandability, the robot should be able to »learn« new environments and objects independently, thereby continuously enhancing its capabilities.

The following parameters and constraints must be met by the learning and detection algorithms:

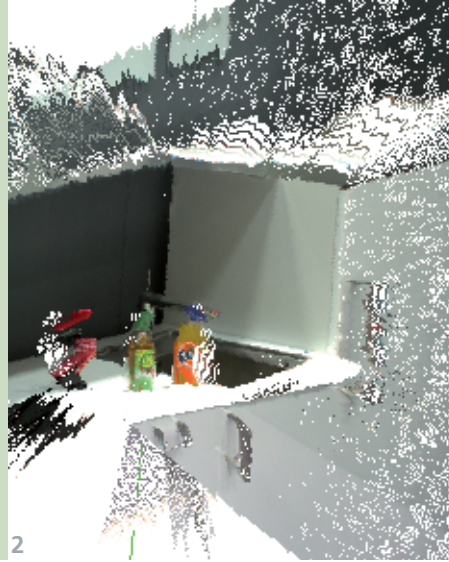
- Detection of the object's position and orientation in all 3 spatial coordinates
- Simple and intuitive teaching of new objects by the user

- High degree of resilience to changes in the lighting conditions at the place of installation
- High degree of resilience to occlusion (up to 80 percent possible)
- Resilience to deformations or partial surface changes
- Detection in less than one second

The below presented process was developed at Fraunhofer IPA for the teaching and recognition of typical everyday objects.

Sensor Setup

Range-image cameras or time-of-flight sensors deliver images similarly to colour cameras, the simple difference being that each pixel contains a distance value instead of the usual RGB values. By combining a range-image camera with a colour camera it is possible to upgrade conventional



2D recognition processes from traditional grey- and colour-image processing into 3D recognition processes. To achieve this, a special calibration between the sensors is used in order to compute an approximate colour image, the pixel coordinate system of which is brought into alignment with that of the range-image cameras. This means that not only the colour value, but also the distance of the respective neighbourhood point is known for each pixel in the image.

Object Representation

Objects are represented by so-called »6D feature point clouds«. These denote a set of 3D points that can be assigned to certain recognizable patterns in the colour and depth images. By combining the colour and depth images it is possible for each feature point detected in the colour image to be associated with a unique 3D position and orientation. In order to define the positions of the feature points assigned to an object with respect to each other, a local coordinate system is computed for each feature point to describe that point's position relative to a coordinate system located centrally in the object.

The described method of object representation is suitable for modelling and detecting various object types, and in some cases even mechanically movable or plastically deformable objects.

Detection of Known Objects

In order to detect a certain object in a given scene, first all the features detected in the scene are joined together to form a feature point cloud of the scene, in which a search is then conducted for possible correspondences with the feature point cloud of the object. For each examined correspondence, it is computed where the central object coordinate system would be in the scene if the feature point actually belonged to the object. From the computed hypotheses, that one is selected with the highest likelihood. Depending on the required accuracy, the procedure is concluded by a refining object localisation. Detection takes around 2 s for an aperture angle of 45°. Accuracy is in the range of 1 to 2 cm according to the resolution and accuracy of currently available range-image cameras.

Teaching of New Objects

Two different learning modes are available for the teaching of new objects: either the object is placed into the robot's gripper and the robot rotates the object while scanning it, or a human shows the object to the robot. The thereby applied learning process consists of the following algorithms, which build on each other:

1. Acquisition of a 3D colour image sequence with different object views
2. Spatial segmentation of the object views on the basis of a 3D mask

3. Computation of stable 6D feature points (3D position and orientation) for all views
4. Fusion of the partial object feature point clouds into an object model

The calculated object model is saved to a file and can be used for detection.

What we offer

The presented process is part of a software library developed at Fraunhofer IPA for 3D image processing. The included algorithms are thereby not limited to the identification of position and orientation of the household items displayed in the examples. Other challenging tasks such as the detection of hand wheels and cow teats have successfully been tackled with Fraunhofer IPA's 3D image processing tools.

Fraunhofer IPA will support you in all phases of development of your customized recognition software: from system design and selection of suitable sensors and image processing techniques through to the development of suitable algorithms to meet your specific needs.

Contact us to discuss your particular application scenario.

- 1 *Autonomous object learning (detected feature points displayed in colour, left)*
- 2 *3D image of a scene*
- 3 *Home assistant »Care-O-bot® 3« grasping a bottle after successful detection*