The b-it-bots@Home 2016 Team Description Paper

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Abstract. This paper presents the b-it-bots@Home team and its mobile service robot called *Jenny* – a service robot based on the Care-O-bot 3 platform manufactured by the Fraunhofer Institute for Manufacturing Engineering and Automation. In this paper, an overview of the robot control architecture and its capabilities is presented. The capabilities refers to the added functionalities from research and projects carried out within the Bonn-Rhein-Sieg University of Applied Science.

1 Introduction

The b-it-bots@Home team at Bonn-Rhein-Sieg University of Applied Sciences (BRSU) has been established in 2007. The b-it-bots@Home team is strongly interwoven with the Master by Research course in Autonomous Systems, which is offered at the BRSU[1]. The main research interests include mobile manipulation, environment modeling, computer vision and human robot interaction (HRI). The team consists of Bachelor, Master and PhD students who are advised by the university's professors. The team serves as a mean for students to integrate their academic project work into a well-functioning robot control software system. Due to the continuous integration process, the team's robot platform has experience many upgrade in terms of hardware and software.

2 Robot Platform

The primary robot platform for the b-it-bots@Home team is the omni wheeled robot Care-O-bot 3 [3] (Figure 3). The Care-O-bot 3 is developed by the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) in Stuttgart, Germany. The Care-O-bot 3 is equipped with a 7 DoF manipulator, a three finger hand and an omni-directional platform, which is powered by 8 motors (2 motors per wheel: 1 for rotation axis, 1 for drive). The side mounted tray can

[1] `www.inf.h-brs.de/MAS`

be flipped up to the front in order to carry multiple objects simultaneously. The sensor head contains a zoomable Stemmer CVC EH6500 HD GE/POE color camera and a Kinect camera. Two SICK S300 laser scanners and one Hokuyo URG-04LX laser scanner are used for mapping and navigation.

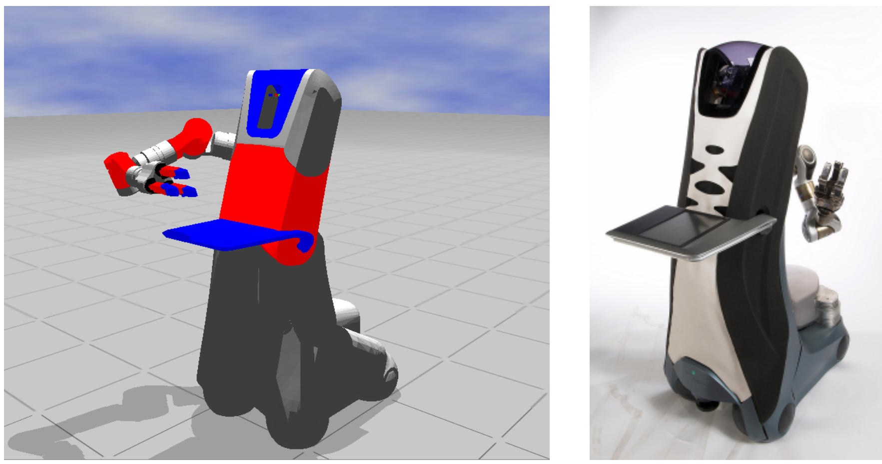

Fig. 1: The team robot: "Jenny", a Care-O-bot 3 service robot.

The robot platform utilized robotic software which are considered as the current best practice in research and application. The robot platform operates using the ROS or Robot Operating System [8] software framework. LINE-MOD [5] and MoveIt![2] are used for object detection and the manipulator's motion planning respectively. In addition of such commonly used software, the team continuously develops new functionality for the robot platform based on its role as a domestic service robot.

3 Functionalities

In this section, the added functionalities for the robot platform is presented. The functionalities are the results of R&D projects, Master theses, and other projects. In most cases, the state-of-the-art and available best practice solution was investigated in the early phase of each project. This activity will be followed by implementation and integration of the applicable algorithms to the robot platform. Finally, a novel or adapted approaches is developed to improve the robustness in performing tasks within an uncertain domestic environment.

[2] `moveit.ros.org`

3.1 Reactive Placement

Safe object placement on a flat surface is achieved by detecting a contact between the object and the environment (e.g. a table). The placement procedure starts by moving the manipulator to a position directly above the desired placement location. This action is followed by the manipulator descends while monitoring the force-torque sensor. The output of the force-torque sensor is smoothen using a moving-average filter, as implemented in [2], and the filtered output is compared to a force threshold. The manipulator's motion is stopped if the monitored force exceeds the threshold value and the hand's fingers are opened to release the object. The advantages of using this approach allows the robot to overcome limitations in the accuracy of visual systems and to also handles changes that might occur in a dynamic environment. More details about this approach can be found in [9].

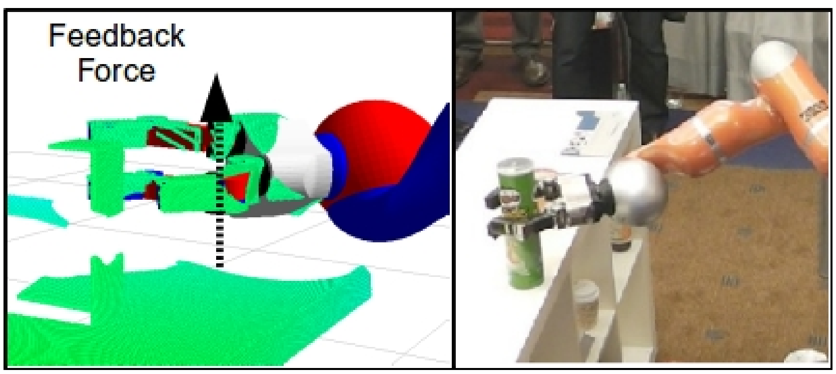

Fig. 2: Reactive placement

3.2 Object Categorization

In service robotics, tasks without the involvement of objects are barely applicable, like in searching, fetching or delivering tasks. Service robots are supposed to capture efficiently object related information in real world scenes while for instance considering clutter and noise, and also being flexible and scalable to memorize a large set of objects. In order to detect object related information in cluttered domestic environments an object detection method is proposed that copes with multiple plane and object occurrences like in cluttered scenes with shelves. Further a surface reconstruction method based on Growing Neural Gas (GNG) [7] in combination with a shape distribution-based descriptor is proposed to reflect shape characteristics of object candidates. Beneficial properties provided by the GNG such as smoothing and denoising effects support a stable description of the object candidates which also leads towards a more stable learning of categories [6].

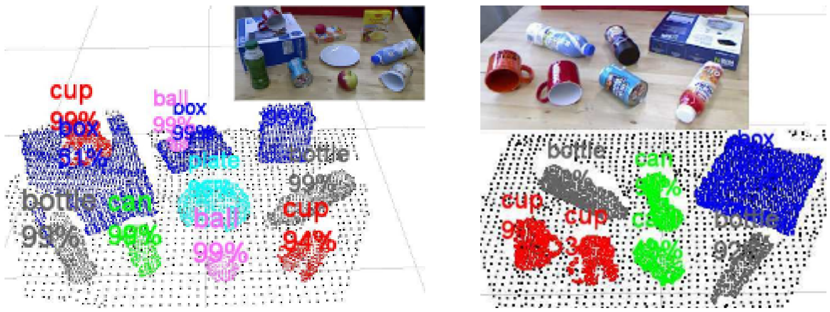

Fig. 3: Household object categorization

Based on the presented descriptor a dictionary approach combined with a supervised shape learner is presented to learn prediction models of shape categories. Experimental results, of different shapes related to domestically appearing object shape categories such as cup, can, box, bottle, bowl, plate and ball, are shown. A classification accuracy of about 90% and a sequential execution time of lesser than two seconds for the categorization of an unknown object is achieved which proves the reasonableness of the proposed system design.

3.3 3D People Detection

The 3D people detection [4] uses the recently available *Microsoft Kinect* sensor which combines the advantages of LRFs (fast, accurate), monocular cameras(color information), and TOF cameras (3D information). The preliminary segmentation is based on a top-down/bottom-up technique which yields the capability of detecting partially occluded person, e.g. behind a desk or cupboard. The information gained from the local surface normals enable the system to detect a person in various poses and motions, i.e. sitting on other objects, bended to the front or side, walking fast/slow. As final machine learning technique, a Random Forest classifier is applied which outperformed the opponents AdaBoost and SVM. The presented approach is able to detect people (see also Figure 4) up to a distance of 5 meters with a detection rate of 87.29% for standing and 74.94% for sitting people.

3.4 Haptic Interface

The manipulator of the robot platform can be utilized to function also as a haptic interface for human user [2]. This functionality have been developed and implemented in two scenarios, *guidance* and *cooperative transportation*. In *guidance*, a

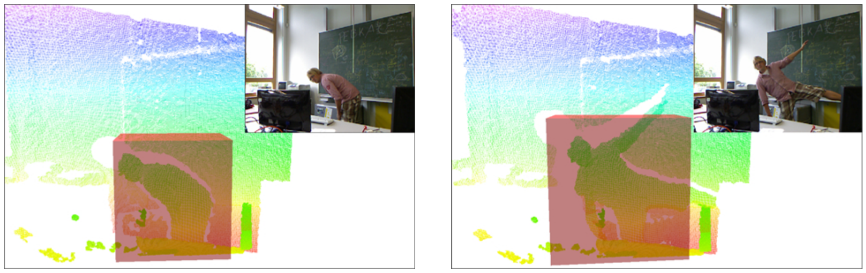

Fig. 4: Detections for various pose configurations.

user can control the robot's base movement trough interacting with the manipulator wrist or gripper. In the second scenario, *cooperative transportation*, the robot can carry an object together with a human user and follow the movement direction. Both scenarios are shown in Figure 5. Through the use of smoothing filter and PID controller, the feature is able accommodate noisy input and produce a steady movement. The feature is developed so that it can be applied in almost all possible configuration. Specifically for *guidance* scenario, a user trial have been performed and the results shows that the functionality is intuitive and compatible for different type of users.

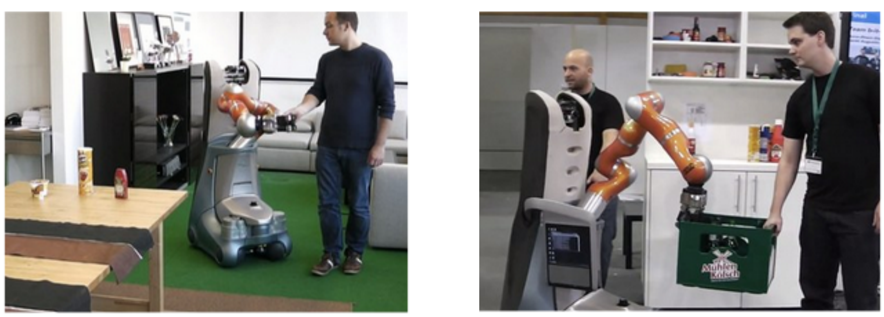

Fig. 5: Manipulator as a haptic interface

4 Conclusion

In this paper the robot platform of the b-it-bots@Home team and its capabilities is presented. The integration of the functionalities in the robot platform is an ongoing process. In the previous EU FP7 funded project BRICS (Best Practice in Robotics) [1], an improved software development methodology in robotics is explored. Among others are the application of the component-oriented development approach defined in BRICS for the software development which turned out to be very feasible when several heterogeneous components are composed into a complete system.

Acknowledgement

We gratefully acknowledge the continued support of the team by the b-it Bonn-Aachen International Center for Information Technology, the Bonn-Rhein-Sieg University of Applied Sciences and the Fraunhofer Institute for Manufacturing Engineering and Automation in Stuttgart for the help and support in providing us the Care-O-bot as a research platform for the RoboCup@Home competition.

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Photos(s) of the robot(s)
Included above in Figures 3 and 5.

Description of the hardware used
Fraunhofer Care-O-bot 3 Omnidirectional base
KUKA LWR 7-DoF Manipulator
Asus Xtion Pro Live
Microsoft LifeCam 1080p
SICK S300 (2x)
Hokuyo URG-04LX

Description of software used
ROS (mix of custom and open ROS packages, including: 2d nav, MoveIt!)
OpenCV
PCL
Nuance VoCon
NEUROtechnology VeriLook