Applied Robotics: Precision Placement in RoboCup@Work (Demonstration)

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ABSTRACT

In this demonstration we show how various approaches from different computer science domains have been combined to win the 2013 world championship title in the RoboCup@Work league. RoboCup@Work aims to facilitate the use of autonomous robots in industry. Among other contributions, we show how artificial intelligence can be successfully reintegrated into a noteworthy robotics solution. This entails (simultaneous) localization and mapping, navigation, object recognition and object manipulation. The platform used is ground based, capable of omnidirectional movement and equipped with a five degree of freedom arm featuring a parallel gripper.

Categories and Subject Descriptors

I.2.9 [**Artificial Intelligence**]: Robotics

General Terms

Algorithms, Experimentation

Keywords

Robotics, RoboCup@Work, Manipulation, Object Detection

1. INTRODUCTION

RoboCup@Work is a recently launched competition which aims at flexible robotic solutions in work-related scenarios. The leagues vision[1] is to "foster research and development that enables use of innovative mobile robots equipped with advanced manipulators for current and future industrial applications, where robots cooperate with human workers for complex tasks ranging from manufacturing, automation, and parts handling up to general logistics".

In contrast to the well developed robotic solutions deployed in common mass-production environments like car production, RoboCup@Work targets smaller companies in which flexible multi-purpose solutions are required, which are not yet available in industry. Example tasks are finding and acquiring parts, transportation to and from dynamic locations, assembly of simple objects etc. From these industrial goals various scientific challenges arise. For example, in perception, path planning, grasp planning, decision making, adaptivity and learning, as well as in multi-robot and human to robot cooperation[2].

[1]`http://robocupatwork.org/`

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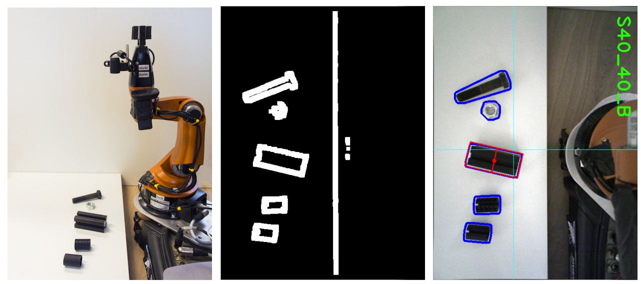

(a) (b) (c)

Figure 1: (a) Pre-grip scan position. (b) Pre-processing of the image. (c) Detected objects, classification and grasp position of the closest object.

2. SWARMLAB@WORK

SwarmLab@work is the team from Maastricht University, that competes in the @Work competition in RoboCup[3]. The team has been established in the beginning of 2013, and has since won the @Work competitions of the 2013 RoboCup German Open and the 2013 RoboCup World Cup. Our robot is based on a stock KUKA youBot. The youBot features mecanum wheels and is capable of omnidirectional drive. For manipulating objects it is equipped with a 5-DOF manipulator and a two-finger gripper. For perceiving the environment, two Hokuyo URG-04LX-UG01 light detection and ranging (LIDAR) sensors are mounted parallel to the floor on the front and back of the robot. In order to detect and recognize manipulation objects, an ASUS Xtion PRO LIVE RGBD camera is installed on the last arm joint. The base computer features an Intel i7 CPU and is supported by

[2]**Disclaimer:** A similar demonstration has been presented at the local Benelux AI conference in Delft (BNAIC'13), the Netherlands. The positive responses received during that conference made us decide to re-submit to AAMAS to present the demo to an international audience.

[3]This team has recently moved to the University of Liverpool, where it is part of the newly established SMARTLab robotics laboratory of the Agent ART group, and now is referred to as SMARTLab@work

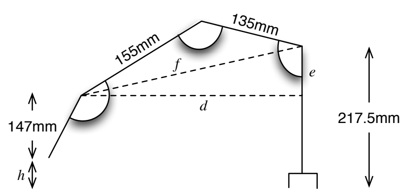

Figure 2: Simple inverse kinematics: d and h are the grip distance and height, relative to the mount point of the arm. By always gripping from a top down position, e and f can be calculated and by that we can determine all angles for the joints.

an i5 notebook, which is mounted on a rack at the backside of the robot. Figure 3a shows the current setup.

3. APPROACH

To tackle some of the previously mentioned scientific challenges, we use particle filter (AMCL) [4] for LIDAR based mapping and localization, a dynamic window approach [3] based trajectory rollout for path planning and a force field [2] approach for recovery behavior.

The navigation is very well suited to navigate between larger distances from different positions in the map. But the accuracy of the navigation and localization is not high enough to navigate with high reproducibility to previously known goals. Thus for aligning to those previously known locations another technique is needed, since we want to be as close as possible to the manipulation areas as possible. Also for the basic navigation test, the markers have to be covered exactly, which is not always the case when using only AMCL for localization. Thus, we implemented ICP based scan registration [6] for fine grain positioning. This techniques records a laser scan at a certain position. When the robot is close to this position, the differences between the current laser scan and the registered one are calculated into a direction which is used to steer the robot to the old position with very high accuracy. By using correspondence rejectors we make sure that slight changes in the environment, e.g. caused by humans standing around the robot, do not interfere with the scan registration accuracy.

Figure 1 shows the steps involved in the object recognition. The robot positions itself such that it has a top down view on the service area as shown in Figure 1a. We use the openCV-library [1] to detect the objects. An adaptive threshold filter is applied to the input image. Afterwards the image is converted into a black and white image and this is used to detect the contours of the objects as shown in Figure 1b. We use various features of the detected objects, e.g., length of principal axis, average intensity and area, and use a labeled data-set that we created on the location to train a J4.8 decision tree in WEKA [5] for the recognition of the objects. This decision tree is then used for the online classification of the objects. Figure 1c shows the detection in a service area.

In order to manipulate the detected objects, the various joints of the arm have to be controlled such that the objects is grasped correctly. We implemented a simple inverse kinematics [7] module to calculate the joint values for any top-down gripping point that is in the reach of the robot. Since we are gripping from a top-down position, the inverse

(a) (b)

Figure 3: (a) shows the modified KUKA youBot, (b) shows an example precision placement test.

kinematics can be solved exactly, when we fix the first joint such that it is always pointing in the direction of the gripping point as shown in Figure 2. Then the remaining joints can be calculated in a straight forward manner, by solving the angles of a triangle with three known side lengths, since we know the distance of the grip and also the lengths of all the arm-segments. The position-reproducibility of the arm is in sub millimeter order, which proved to be sufficient for performing highly accurate grasp and place trajectories.

4. DEMONSTRATION

In the proposed demonstration we will show a “precision placement test”, i.e., acquiring certain objects from a service area followed by transportation to a destination area, where the environment is known in advance, but unmapped obstacles can be placed. Upon arrival at the destination area, the object will be placed with millimeter precision into object specific cavities. The cavities match the outline of the object with 10% tolerance for every dimension. Figure 3b shows an example setup for the precision placement test. In the a video found in the online material[4], we show the proposed demonstration, for which we require a 3x3 meter area of rigid floorspace.

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