Intelligent Robotics Lab

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UvA@Work

Technical Report

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Abstract

The goal of the UvA@Work team is to demonstrate that the KUKA youBot platform is capable of performing a "Professional Task" as defined in the RoboCup@Work challenge. This task specifies a robot that can navigate around a warehouse and manipulate industrial style objects. Over the span of two years the UvA@Work team has provided partial solutions towards solving these challenges.

1 Introduction

The UvA@Work team consists of two Artificial Intelligence (AI) bachelor students supported by a senior university staff member. It was founded at the beginning of the academic year 2013-2014 as part of the Intelligent Robotics Lab[1]. This initiative strives to involve students of the Universiteit van Amsterdam (UvA) in robotics. It also acts as a governing body for all the UvA's robotic teams such as UvA@Work, The Dutch NAO Team [3] (RoboCup Standard Platform League), the Amsterdam Oxford Joint Rescue Forces [2] (RoboCup Rescue Simulation League) and Maneki-Neko [8] (Micro Air Vehicle competition) to guarantee continuation of research, education and competition experience. It also enables sharing any gathered knowledge between the different teams.

After its first competition experience with the Kuka youBot at the RoCKIn Camps 2014 in Rome, the UvA@Work has made progress towards a robotic solution in a warehouse environment. The RoboCup@Work track describes different challenges in the field of perception,manipulation and navigation. The main purpose of these challenges is to design a autonomous robot that can navigate itself in the test area and to manipulate industrial style objects such as bolts and nuts. The challenges set out by the RoCKIn@Work organisation are designed to drive both the level of scientific research and the industrial achievements forward. A warehouse environment is simulated by creating borders and platforms, some of which labelled with data-matrices which can be used to identify or localise objects. During the challenges, two robots will be active in the simulated warehouse, not only does the robot belonging to the team have to complete its challenge, it also also has to avoid collisions with the other robot. One of the challenges could be to transport one item from a location to another location, another would be the visual inspection of an object and determining if it belongs to either category 'A' of object or category 'B'.

In the following sections the contributions of the UvA@Work team towards a solution of these challenges will be explained in detail. First however the, hardware, used libraries and frameworks are listed.

2 Hardware, libraries and framework

2.1 Hardware

The KUKA youBot used by the UvA@Work team is equipped with a sensor suite consisting of an Asus Xtion Pro Live to create a disparity map, a Hokuyo UTM-30LX laser scanner for occupancy grid mapping and a Microsoft LifeCam HD-5000 for RGB vision as can be seen in Figure 1. The Asus Xtion Pro is mounted well above the youBot platform to allow for a broad view of the local surroundings. These broad overviews can be processed as both, RGB and depth images. The Hokuyo UTM-30LX laser scanner is mounted in front of the youBot platform and provides a high precision depth plane over a 270 degree angle. Finally, the Microsoft LifeCam HD-5000 is mounted on top of the youBot's end effector to assist pick-up and placing tasks.

In addition to these sensors the Creative Senz3D, a close range depth camera, was used instead of the Microsoft LifeCam HD-5000 to experiment with an active vision setup.

Being part of the KUKA Innovation Challenge [7], the UvA has had temporal access to a second, sponsored youBot.

[1] `http://www.dutchnaoteam.nl/index.php/irobolab/`

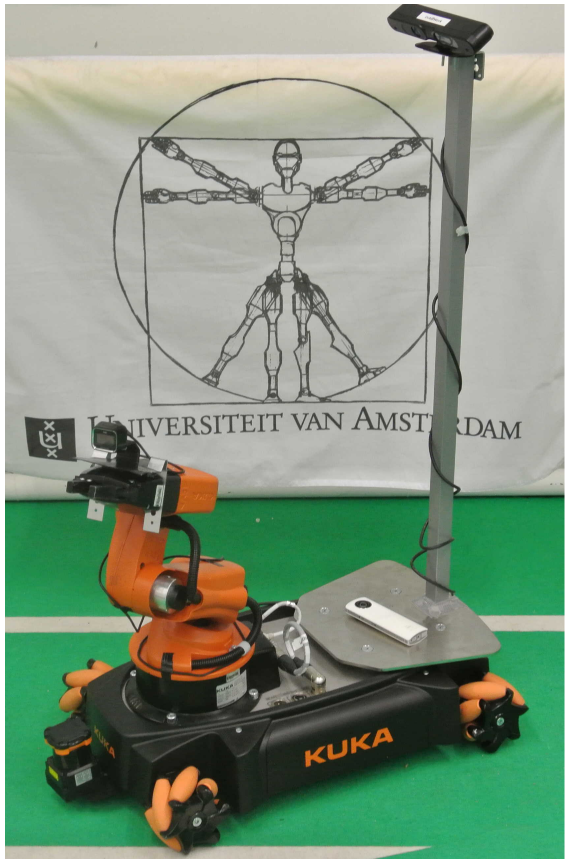

Figure 1: The Kuka youBot mounted with all its sensors: Asus Xtion Pro Live, Hokuyo UTM-30LX and a Microsoft LifeCam HD-5000.

2.2 Libraries

When processing visual information the Open Computer Vision Library (OpenCV)[2] is a very helpful library as it provides many implementations for various computer vision algorithms.

2.3 Framework: Robot Operating System (ROS)

ROS is a broadly used framework for robotic application development. It supplies an easily extensible environment of basic components (nodes) which can be combined flexibly to form applications. ROS also provides a parameter server which allows nodes to use shared parameters. In the current implementation these shared parameters are used to change the local workings of each node depending on the task that needs to be carried out. Furthermore, ROS comes with a range of packages, libraries, drivers and simulation programs that simplify the use of standard platform robots. For the development of implementations on the KUKA youBot, the team of UvA@Work uses the ROS

[2] `http://opencv.org/`

Hydro Medusa version.

3 Image Processing

The Image Processing Pipeline (IPP) currently consists of 7 nodes: webcam_controller, openni2, image_controller, image_thresholder, datamatrix_detector, tag_detector and object_detector.
The webcam_controller takes care of retrieving image streams from the different RGB cameras mounted on the robot. In the current implementation, only one camera can be used at a time due to limitations in data capacity of the USB-bus. To work around this limitation, the active camera can be assigned depending on the current task by using ROS parameters. For depth cameras the standard ROS package Openni2 is used. These two packages send their images to the image_controller node. Depending on the ROS parameters specified, the received input is passed on to the right detector and/or image_thresholder node. The detectors are used to locate data matrices, tags (coloured sheets) or objects (as specified in the @Work-rulebook) in the image frame. These detectors also rely on the use of the OpenCV2 library. Finally, the detectors send obtained features to the action_controller.

3.1 Blob Tracking

In order to first familiarise with the hardware a colour blob tracker was created. By first transforming the images received from the camera mounted on the end-effector of the robot to the HSV colour space and then thresholding these images, the largest blob could be identified using OpenCV. The returned location of the largest blob in the image represents an error when compared to the desired location of the largest blob, which in the case of a tracker is the centre of the image. The arm is then moved in such a way that the error is decreased and thus the largest blob is centred in the image resulting in the tracking of object at hand.

3.2 Data Matrix tracking

As data matrices are used in the RoCKIn to both identify objects and provide landmarks a reliable way of recognising them needed to be created. During the RoCKIn Camps in 2014, a basic application was provided. This application was modified in order to work with the standardised ROS messages. While subscribing to the image stream provided by the different cameras the pose estimations of the positions of the data matrices relative to the camera's are published on another stream. These streams are identified by topic names as is custom to the ROS framework. With the different identifiers that are provided in the data matrices, a simple mapping from this identifier to the actual object or position of the data matrix provided a successful way of recognising the objects and positions.

3.3 Active Vision using Template Matching

As part of a bachelor thesis [5] active vision with the use of template matching on both colour and depth images was investigated. The intention was to show the combination of depth information and colour information in correlation coefficient template matching to drive an active vision algorithm with the goal to optimise the amount of perspectives that are required to correctly identify an object

Figure 2: An example of two template matching search spaces fused into one.

from the RoCKIn@Work competitions. The resulting search spaces from the template matching algorithm of both type of images (depth and colour), obtained from a Creative Senz3D RGB-D camera, were fused as can be seen in Figure 2. The results from the fused search space were compared to those of the search space created from the colour images. The templates, that are labelled with an object pose, were also validated for their maximum score. This maximum score was used to generate the new perspective to which the camera moved and from where it is most likely to obtain a higher score then from the current perspective. The results showed that although the depth information does increase the score that represents the presence of the object in the image, which provides a safety margin and a score that is more robust against changes in lighting conditions, that a reduction in amount of perspectives required to correctly identify an object can not be made.

4 Manipulation

4.1 The Fabrik Inverse Kinematics Algorithm

Another challenge that requires exploration is the manipulation challenge. This could be picking up and precisely placing one of the industrial parts of the RoboCup and RoCKIn@Work challenges. Being a Dutch team however the UvA@Work decided to also specialise on a different exercise: agriculture is a very important sector in the Netherlands and the Uva@Work is investigating if it is possible to let the youBot find and pick up a specified flower [6].

The UvA@Work team has implemented the Fabrik algorithm [1] in order to work with the dimensions of the Kuka youBot. This algorithm uses basic geometric shapes to iteratively move the end-effector closer to the end goal. This implementation is fast enough to allow real-time geometric shape following and from design provides a smooth approach of the goal position. As a demonstration for the 'Director of Innovation' of KLM [3] 4 line segments were chosen that together represent a square in front of the robot. By using a parameter δ the distance between the two points along one of these lines can be adjusted. By using a value δ of 0.005 centimetre, high precision movement can be achieved while still maintaining a low enough computational time allowing for real-time movement. While instead only providing an end position that is to be reached instead of a line segment that is to be followed, the intermediary results can be used to slowly approach the end position as is required to prevent an overshoot from happening. When the end effector is close to the end position an maximum error must be chosen as the iterative algorithm never reaches the

[3] http://klm.nl/

exact goal position.

As the algorithm can be run in real time and naturally prevents overshoots from happening when using the intermediary results as poses while approaching the goal position, the UvA@Work team concludes that the Fabrik algorithm is suitable for challenges that need to be completed with the youBot.

5 Human Robot Interaction (HRI)

In context of the RoCKIn Camp 2014 in Rome, the UvA@Work team started working on a Spoken Language Understanding (SLU) application for optimised customer-robot interaction. As SLU allows for a native communication with the robot, Human Robot Interaction is tailored for real-word use.
Spoken commands are recorded by an attached microphone and sent to the online Google voice recognition service. The returning result in form of written words is fed to a language model system, tagging words and applying a grammatical structure. As a next step, contained objects and actions are grounded in reference to a prebuilt database of environment and robot. These grounded objects and actions are than used to create a series of commands that can be send to the task_manager node within the ROS framework - thus conversed into a language that is "understood" by the robot. Tested in RoCKIn Camp Rome were basic directional commands as well as emergency "STOP".
This SLU interface can also be used as an alternative to the standard command-line @Work interface used to specify the task to be carried out.

6 Visual Odometry with the Ricoh Theta

The Ricoh Theta camera is a full 360 degree spherical camera with two lenses, where the images obtained are automatically stitched together. Initial calibration efforts indicate that the images are stored in perfect spherical projection. As a result, the image can directly be wrapped around a unit sphere. This means that every image point has the same centre of origin, which makes conversions to other projections (perspective, panorama or bird-eye view) easily possible.

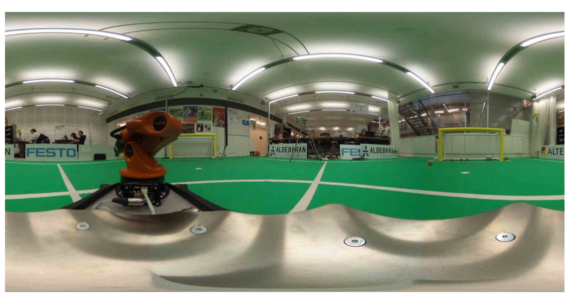

Figure 3: Image captured with a Ricoh Theta from the KUKA youBot.

When mounted on a moving platform, both the disappearing points are visible (which indicate the direction of movement) as well as a ring of maximal optimal flow, which can be used to estimate the amplitude of the movement. Currently, orientation can already accurately be estimated from the optical flow, an accurate estimation of the translation is under study [4].

7 Conclusion

As shown in the previous sections, the UvA@Work team has worked towards solutions for the various challenges provided by the RoCKIn@Work organisation. Although many different sub parts of those challenges have been solved, there has never been a full solution to multiple challenges which is why the UvA@Work team has not participated in the actual matches provided by RoCKIn@Work. Because of this no direct comparison can be made to the results of the other teams active in the @Work league. Nevertheless, over the span of two years, the Uva@Work team has invested a lot of time and effort into researching various solutions towards the challenges with various amounts of success.

References

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