A Knowledge-Based Approach to Robotic Perception using Unstructured Information Management

(Demonstration)

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ABSTRACT

In order to achieve a human-like skill level in manipulation, autonomous robots that perform everyday manipulation tasks require perception capabilities that go beyond recognition delivered by single perception algorithms. In previous work we have presented ROBOSHERLOCK, an ensemble-based, knowledge driven robotic perception system and OPENEASE an online framework for knowledge representation and reasoning. We propose to demonstrate, by combining these two frameworks, how knowledge processing can boosts the perception capabilities of a robotic agent performing household chores.

Categories and Subject Descriptors

I.2.10 [**Artificial Intelligence**]: Vision and Scene Understanding—*3D/stereo scene analysis, Perceptual reasoning, Architecture and control structures*

Keywords

robot perception, knowledge based reasoning, personal robotics

1. INTRODUCTION

An autonomous robotic agent acting in a human environment needs to be equipped with powerful perception capabilities. It needs to reliably detect objects that possess very different perceptual characteristics (textured, untextured, shiny, translucent etc.) and that are found in challenging environments (clutter, occlusion). Recent research in robotic perception has focused on advancing subsets of these characteristics on an algorithmic level, and has made considerable advances — but there is still a large gap between the perceptual capabilities needed for performing human-like manipulation and those that are currently available. This is partly due to the fact that there is no single perception algorithm that can handle the diversity of characteristics that objects possess, and partly because robot perception needs to go beyond the task of categorizing/labeling objects.

We therefore propose to synergistically combine multiple algorithms in a coherent framework such that each of them contributes its particular expertise to the overall task. To this end, we consider the robotic perception task as a query-answering problem that is to be solved by combining multiple perceptual experts with a formal knowledge processing framework that can supply background knowledge and context information. ROBOSHERLOCK [**?**] is an autonomous perception agent built on these principles. In this demonstration, we will present an application of ROBOSHERLOCK combined with OPENEASE [**?**], an online knowledge representation and processing service, where the task of the robot is to answer queries about the objects that it perceives, to reason about them, and to modify its processing components if needed in order to successfully complete a given perception task.

OPENEASE[1] is an unprecedented web based knowledge service for robotic experiments. The service is intended to be used by researchers in robotics in order to comprehend and reproduce experimental results, to examine the experimental log data and to test and improve implementations of inference methods for real-world scenarios. The knowledge base that is used by the OPENEASE service incorporates (1) a big-data database containing continuous log data of complex manipulation tasks performed by robots and humans; (2) an ontology, i.e. symbolically represented information, including common sense knowledge about involved items as well as knowledge about when and why an action was performed, how it was performed, the effects of the action and what the robot believed when the action was executed; (3) and software that allow to query, visualize, and analyze the manipulation episodes.

2. THE ROBOSHERLOCK SYSTEM

ROBOSHERLOCK is a perception framework for robots performing human-scale everyday manipulation tasks. It allows combination of the strengths of multiple perception algorithms("experts"), to boost object recognition performance, and supports knowledge-enabled reasoning on the results of the experts. The architecture has been implemented using the "Unstructured Information Management Architecture" [**?**], an open-source architecture that has been developed in the context of the IBM Watson system.

ROBOSHERLOCK processing modules are organized in pipelines. Each pipeline consists of multiple experts and adds a certain functionality to the overall system. For example, the "Pervasive Calm Perception" pipeline PERCAP [**?**] maintains a preparatory belief state that is constantly being updated in the background to speed up high-level perception tasks. Another pipeline is tasked with answering queries through knowledge-driven generation of processing pipelines that are specifically configured to the needs of that query. Those generated pipelines then execute different high-level perception routines that use the preparatory belief state.

The experts in ROBOSHERLOCK, their required inputs and the outputs produced are represented in a knowledge base, enabling

[1] `www.open-ease.org`

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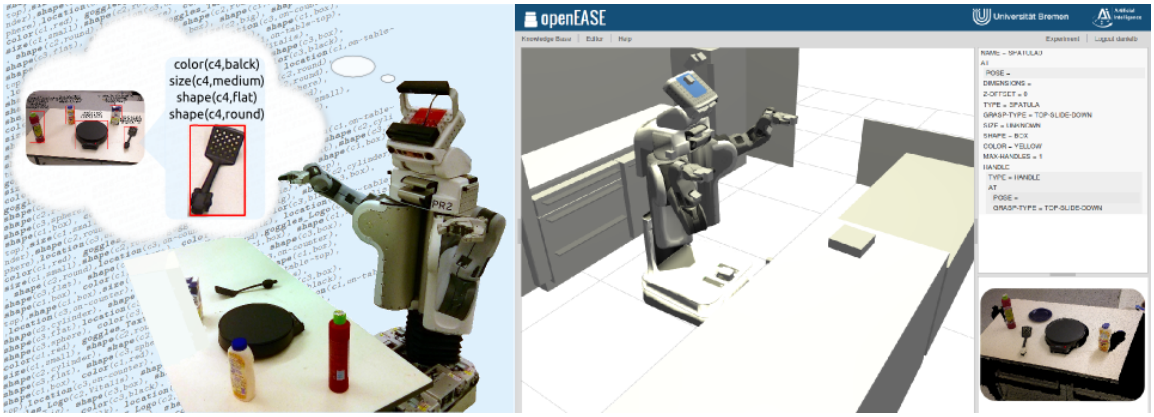

Figure 1: PR2 looking at a cooking scene and the visualization canvas for it in OPENEASE

reasoning about their capabilities. Queries to the perception system are formulated as detection-tasks and are interpreted based on a predefined dictionary. This allows us to answer queries that combine information from multiple experts that may span different modalities, such as the object's category, shape and volume:

(detect (an object
(category container)
(capacity ($\geq$ 1 liter))))
(shape round)

Initially the system reasons about the query, generating the list and order of the experts that it needs to execute. During execution the experts in ROBOSHERLOCK generate object hypotheses and annotate these with symbolic representations (e.g. shape, color, location) that are logged in a knowledge base. Sensor data as well as intermediary results of the system are stored in a MongoDB. With the help of OPENEASE we can query the logged data as well as the capabilities of ROBOSHERLOCK.

Since the expert algorithms are applied independently of each other, their outputs may be complementary, overlapping or even contradictory. ROBOSHERLOCK integrates an engine for learning of and reasoning about probabilistic first-order knowledge bases, which we use for consolidation of inconsistent annotations. First-order probabilistic models can be used to combine the strengths of different expert algorithms and that performance of object recognition systems can be significantly boosted [**?**].

3. DEMONSTRATION SCENARIO

During the course of the proposed demonstration participants will have the chance to see the perception system running on logged sensory input from a PR2 robot performing perception tasks in a kitchen environment, where objects in the scene will be chosen such that they posses different perceptual properties. This part of the demonstration will be similar to the scenario shown in our attached video[2].

A second part of the demonstration will involve participants having the chance to try out predefined queries and also formulate perception queries of their own using the web-based interface of OPENEASE. This part of the demonstration will offer an in depth view into how the procedure of choosing experts works, which experts ROBOSHERLOCK would choose in order to answer the queries successfully, what the limitations are and in failure cases, what went wrong. Participants will also have the chance to query logged perception results from the conducted experiments, where results produced by the system will be shown.

[2] `http://youtu.be/ECw-FSSD9K0`

4. CONCLUSION AND FUTURE WORK

We propose to demonstrate how knowledge processing can play a key role and boost the successful detection of objects of daily using ROBOSHERLOCK. Through the web-based knowledge service OPENEASE we plan to allow participants to try out capabilities of the system and familiarize themselves with the way unstructured information management is successfully used in robotic perception. In the future we plan to allow live execution of perception pipelines on the logged data.

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