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Nao in the Cloud

Knowledge Sharing for Robots via Cloud Services

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***Abstract*—This paper deals with the subject area Knowledge Sharing for Robots. It demonstrates how robots can improve their learning mechanism via Cloud Computing and it shows how heterogeneous robots can exchange information about plans, objects and environments among each other. This work introduces our current research which realizes the approach with the aid of the humanoid robot Nao and the cloud service RoboEarth. The practical part implements an interface between the Nao and the cloud service and demonstrates a use case in which several Nao robots download and execute abstract plans from RoboEarth. So Robots are no longer on one´s own - they can benefit from the experience other robots.**

***Keywords*—Knowledge Sharing; Cloud Robotics; RoboEarth; Robotic Operation System; Nao; Cloud Computing**

I. Introduction

The Internet has become one of the most important communication media. It gives us the opportunity to publish and retrieve knowledge globally. We are able to solve unknown tasks efficiently and share knowledge with other people. If you are involved in the research area of robotics, it would be preferable to apply this paradigm to robots. The problem of the robots is that they are limited in many ways. The computing power and hardware resources are bounded by cost and their physical properties. Moreover, robots are usually on one´s own and only programmed for one specific area. So their behavior is greatly limited by inflexible programming. It is not possible that heterogeneous robots can share executable information among each other. Nowadays, companies like Aldebaran Robotics and Willow Garage are able to deliver wireless capable and programmable robots with abstract interfaces. The specific tasks, such as face recognition, voice recognition and path planning are already efficiently solved. Thus the preconditions have been created to connect robots with the internet. Kuffner [1] and Quintas et al. [2] have introduced the topic Cloud Robotics. This idea provides a physical separation between the hardware and software components of the robot. The conventional hardware devices of a robot, such as sensors, actuators, cameras and speakers are still on the robot. The difference to the usual approach, which designs the software on the robot, is that the brain of the robot is outsourced to remote servers. This consideration to outsource complex and computationally intensive operations to remote servers has already been researched in the 1990s by Inaba [3]. His idea was to equip robots without a brain. At this time there were no processors as nowadays, which are powerful and space saving at once. Inaba tried to minimize the needed hardware resources. In the approach Cloud Robotics represents the robot a client that consumes services from the cloud infrastructure and the server-side specifies a cloud of servers. This approach can be used as Inaba [3] to outsource time consuming tasks on powerful remote servers. In addition, it offers the possibility that robots communicate with each other to improve their learning mechanism. The idea of knowledge sharing for robots describes the problem how to exchange information between heterogeneous robots to benefit from the experience others.

II. Related Work

Recently, more and more companies and universities are interested in researching the topic of knowledge sharing for robots via Cloud Computing. The work of Arumugam et al. [4] presents DaVinCi, a Cloud Service for robots to swap out computationally intensive robot algorithms like image processing or path planning to remote servers. DaVinCi uses the Map-Reduce method to parallelize common robotics algorithms. It focuses on the aggregation of sensor data from heterogeneous robots to create global maps. Another similar approach by Fan and Handerson [5] developed a search engine like Google for robots. Robots can request the knowledge repository RobotShare for information about objects and plans. The knowledge is efficiently indexed. When robots request the web repository for something like how to wash cookware, they get the URL-reference of the knowledge. Thereby the received information is defined in natural language and isn`t executable. Zweigle et al. [6] introduced RoboEarth which represents a World Wide Web for robots. This Cloud Service can be used by heterogeneous robots to share information among each other. RoboEarth isn´t only a database for knowledge sharing. Beetz, Mösenlechner and Tenorth [7] have developed the CRAM System which includes mainly the Cognitive Robotic Abstract Machine Plan Language and KnowRob for knowledge processing and reasoning. With the aid of CRAM, robots are able to send semantic requests for a plan to the database. The CRAM System translates the abstract plan like *grasp a bottle* to the CRAM Plan Language, which is a Lisp-like language for the implementation of abstract plans. If a robot is compatible with the open source middleware ROS [8] (Robotic Operation System), it can execute CRAM-Plans. Another approach is using the Google object recognition engine Google Goggels. Usually a Smartphone can send an unknown picture to this service to get information about it. Kehoe et al. [9] realize a cloud-based robot grasping system with the aid of Google Goggels.

III. Nao in the Cloud

The first step to link heterogeneous robots among each other via the cloud is to use a middleware like the Robotic Operation System from Willow Garage. ROS is developed by Quigley et al. [8] and represents an abstraction layer over the robot specific hardware. This meta operation system is extendable with modules. There are modules for many robots like Nao, Oddwerx and PR2. Thanks to RoboEarth, robot specific information about objects, environments and plans are exchangeable between different robot platforms. The focus on this work is that Nao robots can download and execute abstract plans like picking and place an object or how to play the game memory. The next figure shows an architecture for connecting Nao robots with the cloud Service RoboEarth.

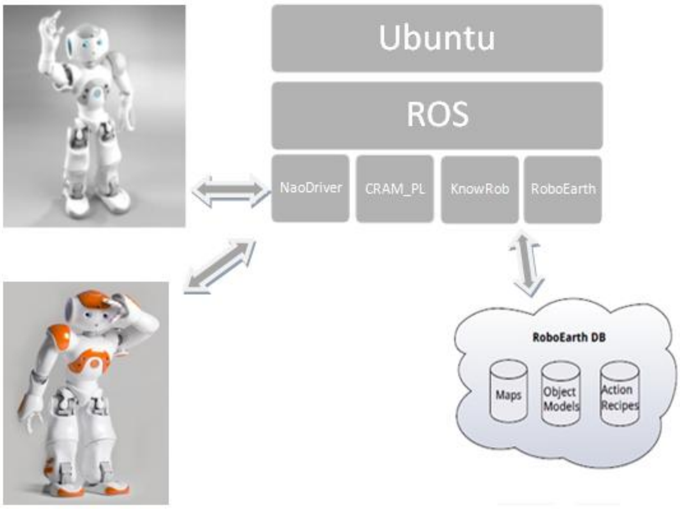

Figure 1: Nao in the Cloud [10, 11]

RoboEarth stores the information in an ontology web language-like format. If a robot sends a semantic request for a plan like *grasping a bottle* to RoboEarth, KnowRob scans the database and translate the requested plan to the Cognitive Abstract Plan Language. The ROS-LISP interface provides the execution of such a CRAM-plan on the robot.

The next code lines show a Prolog-based request for *grasping a bottle*.

```
re_download_action_recipe('Grasp Bottle', 'Nao', Recipe).
re_generate_cpl_plan(Recipe, CplPlan).
```

Listing 1: RoboEarth-Query [12]

The KnowRob component checks the capabilities of the robot against the requirements of the task and generates the CRAM plan for the requested task.

```
(def-top-level-plan grasp-bottle ()
  (with-designators
    ((fridge (object '((type fridge)))
     (bottle-loc (location `((inside ,fridge))))
     (bottle (object `((type bottle) (at ,bottle-loc)))))
    (setf fridge (perceive-object fridge))
    (achieve `(object-in-hand ,bottle :right))))
 …
```

Listing 2: CRAM-Plan [13]

This code must be mapped to the Nao specific commands of the Nao-ROS module.

IV. Outlook

The concrete target of this work is to present the still unexplored approach of knowledge sharing for robots via Cloud Computing. The Nao robot and the cloud service RoboEarth will be used for the implementation. The practical part of our research includes the implementation of an interface between the humanoid robot Nao and RoboEarth cloud service, as well as the realization of a scenario in which several Nao robots download and execute information from the cloud service.

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