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| Authors: | T. Asfour, A. Bierbaum, K. Welke, K. Huebner, P. Azad, M. Popovic, D. Kraft, D. Kragic N. Krüger and R. Dillmann |
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| **Dissemination Level** | | |
| **PU** | Public | **X** |
| **PP** | Restricted to other programme participants (including the Commission Services) | |
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## Abstract:

In this deliverable we present the ongoing work on the humanoid robot ARMAR-III towards the implementation of a humanoid robot system equipped with advanced sensorimotor primitives. In particular, the deliverable presents the progress in the context of vision-based object grasping of known and unknown objects as well as multisensorial exploration of unknown objects.

**Keyword list:** Grasping using a humanoid five-finger hand; multisensorial determination of object properties, object deformability.

# Table of Contents

# 0. Executive Summary

This deliverable presents the sensorimotor primitives that have been realized and tested on the humanoid robot ARMAR-III. These primitives are concerned with vision-based grasping of known and unknown objects as well as the multisensorial exploration of objects.

The deliverable consists of three demonstrations:

- Grasping of a-priori known objects using an object box decomposition algorithm, which has been integrated on ARMAR-III as reported in D1.2.2.
- Grasp reflex: grasping of unknown object using 3D object features provided by an early cognitive vision system, which has been integrated on ARMAR-III as reported in D1.2.2.
- Multisensorial object exploration of unknown objects using a new sensor system and a hybrid position/force controller for the five-fingered robot hand.

# 1. Grasping based on box decomposition on ARMAR-III

The video **BoxGrasping.avi** demonstrates the framework for grasping of known objects based on the box decomposition approach, which has been integrated on the humanoid robot ARMAR-III (see deliverable D1.2.2). The box decomposition approach was developed to approximate 3D point clouds by boxes as simple shape primitives (see [3],[4]). It has been shown that box decomposition of shape is valuable for pre-grasping when only crude object shape information is available. Given the necessary object recognition and pose estimation skills on ARMAR-III ([1], [2]), grasp generation methods can be applied to known objects in order to assign a set of grasp hypotheses to each object model.

In the experiments a-priori known, textured household objects were used. The object models were acquired in the Karlsruhe Object Modeling Center[1] using a high accuracy laser scanner (Minolta VI-900), which provides 3D point clouds and high quality meshes with different resolutions. Texture-based object recognition and pose estimation were implemented using information from that database. The object models are used as input to the box decomposition algorithm to perform object decomposition into 3D boxes. Grasp hypotheses are generated based on the 3D box representation using the GraspIt! simulator.

During the experiments, the objects were presented on a kitchen sideboard. The recognition system identified the objects and the corresponding pose. Given the object pose, the grasp hypotheses generated by the box decomposition approach were ranked according to the robot's reachability. The video shows the execution of the best ranked hypotheses for each object. The execution of grasps combines an approaching phase, which has been realized using a probabilistic solver for the inverse kinematics problem taking into account natural arm postures and a grasping phase which has been realized using position-based visual servoing.

[1] wwwiaim.ira.uka.de/ObjectModels

## 2. Grasp Reflex on ARMAR-III

The video **GraspReflex.avi** demonstrates the progress toward grasping of unknown objects and shows the first implementation of the grasp reflex on the humanoid robot ARMAR-III. As reported in deliverable D1.2.2, both the grasp reflex (see [5], [6]) and the Early Cognitive Vision (CoVis) system (see [7]) have been integrated on the humanoid robot ARMAR. The grasp reflex is implemented as a grasping strategy that does not make use of any specific object prior knowledge. The strategy makes use of second-order relations between visually extracted multi-modal 3D features provided by CoVis. More specifically, the algorithm is based on two relations covering geometric information in terms of a co-planarity constraint as well as appearance based information in terms of co-occurrence of color properties.

The attached video demonstrates grasping of several unknown objects on ARMAR-III, where CoVis and the above-mentioned grasping strategy were used to generate grasp hypotheses. For the experiments several objects were placed on a kitchen sideboard. For a given unknown object, a set of grasp hypotheses was generated. Those that are not feasible due to the robot's kinematics constraints (reachability workspace and joint limits) are then discarded. Finally, the remaining feasible grasps for either the robot's left or right hand are manually selected and executed using a probabilistic solver of the inverse kinematics problem and position-based visual servoing.

The generated grasp hypotheses were initially implemented for a parallel gripper of the SDU robot platform. For the experiments on ARMAR, a simplified mapping from the parallel gripper to the humanoid five-fingered hand was used. A verification of the grasp success has not yet been performed.

## 3. Haptic Object Verification and Deformability Assessment on ARMAR-III

This video demonstrates the capabilities of the developed haptic sensor system and the hybrid force position controller for ARMAR's five-fingered hand. The robot's task is to haptically verify the "objectness" at a given position, i.e. to verify the existence of an object at that specific position. For this purpose, the new sensory system and the hybrid position/force controller for the five-fingered robot hand were used. The complete sensory system comprising nine miniature pressure and eight joint position sensors has been integrated into the left hand of the humanoid robot ARMAR-IIIb. A low-level controller has been developed, which allows for the specification of both pressure and position targets for the joint actuators of the eight degrees of freedom of the robot hand (see [8]).

In the presented experiment, the fingers were closed in order to grasp an object at a given position while applying a predefined force on it. Once the object is detected, the robot picked the object and started to assess its deformability by further increasing the applied finger force. The finger positions were determined using forward kinematics. A set of deformable and rigid objects were sorted into the corresponding box on the table. "Non-objectness" is detected when no object exists at the pick-up position.

## References

[1] Asfour, T., Azad, P., Vahrenkamp, N., Regenstein, R., Bierbaum, A., Welke, K., Schröder, J. and Dillmann, R. (2008). Toward humanoid manipulation in human-centred environments. Robotics and Autonomous Systems, 56(11):54–65, 2008.

[2] Azad, P., Asfour, T. and Dillmann, R. (2007) Stereo-based 6D Object Localization for Grasping with Humanoid Robot Systems. In IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pages 919–924, San Diego, USA.

[3] Huebner, K. and Kragic, D. (2008a) Selection of Robot Pre-Grasps using Box-Based Shape Approximation. In IEEE International Conference on Intelligent Robots and Systems, pages 1765–1770.

[4] Huebner, K., Ruthotto, S. and Kragic, D. (2008b) Minimum Volume Bounding Box Decomposition for Shape Approximation in Robot Grasping. In IEEE International Conference on Robotics and Automation, pages 1628–1633.

[5] Popović, M. (2008) An Early Grasping Reflex in a Cognitive Robot Vision System, master thesis, (http://www.mip.sdu.dk/covig/publications/Mila_Master_Thesis.pdf).

[6] Popovic, M., Kraft, D., Bodenhagen, L., Baseski, E., Pugeault, N., Kragic, D., and Krüger,N. (2009) A strategy for grasping unknown objects based on co-planarity and colour information (submitted).

[7] Krüger, N., Lappe, M. and Wörgötter, F. (2004) Biologically Motivated Multi-modal Processing of Visual Primitives. Interdisciplinary Journal of Artificial Intelligence the Simulation of Behavior, AISB Journal.

[8] Schill, J. (2009). Model-based Force-Position Control and Diagnostics for a Pneumatic Humanoid Robot Hand. Master thesis, Institute for Anthropomatics, University of Karlsruhe.