FP6-IST-002020

COGNIRON

The Cognitive Robot Companion

Integrated Project

Information Society Technologies Priority

D7.4.1
Set-up of the experiment "Learning Skills and Tasks"

Due date of deliverable: December 31 th 2004
Actual submission date: January 15th 2005

Start date of project: January 1st, 2004 **Duration** : 48 months

Organisation name of lead contractor for this deliverable:
EPFL

Revision: final
Dissemination level: PU

Executive Summary

This report summarizes the progresses made from month T6 to month T12 in setting up the key experiment 3 "Task and Skill learning". The work involved in total 3 person/month divided across 7 partners (EPFL, IPA, UKA, VUB, LAAS, KTH, UH). It was carried out to satisfy the requirements of Research Area (RA) 7 as outlined in Work Package (WP) 7.4 to meet the 6 month target, Deliverable 7.4.1, according to the milestone "to define the infrastructure, platforms and basic abilities required for conducting the experiment". It must be made clear that the present report, and, more generally, the WP7.4 activity deals essentially with the design and hardware implementation of the KE3. The core of the scientific approach underlying the development of each of the Cogniron functions, necessary for the implementation of the present KE are reported in the deliverables of the related RAs. The reader should, therefore refer to the respective COGNIRON project documents for details on RA7, WP7.4, Key-Experiments 3 and related COGNIRON Functions (CFs).

Role of the Specification Document in Cogniron

The key experiment 3 plays an integrative role within the whole project, bridging results gathered in research activities RA2, RA4 and RA6. Principally, it aimed at putting forward the general aspect of the learning components developed within each Ras. For this reason, it was decided to duplicate and demonstrate the learning cognitive function within two scripts, implemented on two different platforms. The first script is concerned with *Learning Skills: Arranging and interacting with objects,* while the second script is concerned with *Learning Tasks: Serving a guest*. The scripts and their relation to the Cogniron function are described in deliverable D.7.1.1. For consistency and entirety of the present report, we include only a summary of the above in the following.

1 Report on Key Experiment 3

Script1: "Learning Skills: Arranging and Interacting with Objects"

The script stresses the discriminative abilities of the robot companio, and the robot's ability to learn from implicit (imitation learning) and explicit (verbal interaction) teaching. The script illustrates a situation in which the robot learns new skills to manipulate objects by observing a human demonstration. The demonstration is repeated several times. Each demonstration is slightly different from the other. The order that the objects are manipulated may change, as well as the relative positions and displacements of the objects. The absolute position of the objects may vary as well. While watching the demonstrations, the robot learns to discriminate between relevant and irrelevant behavior. Irrelevant behavior might include mistakes or variations of the motion with no effect on the ultimate goal of the task. The relevant features are, on the other hand, the relative position and orientation of the objects with respect to one another and the specific skills to apply in order to manipulation certain objects. Once the demonstrations are finished, the robot will try to reproduce the task. While doing so, the robot might query the user if some demonstration were ambiguous and its choice is non deterministic. The user might stop and correct verbally the robot during the reproduction, if the robot makes important mistakes.

Relation to Cogniron Functions:
This script is directly demonstrate the Cogniron functions *Learning to Reproduce Gestures* CF-RG, *Learning Important Features of the task* CF-LIG, *Person tracking and detection of attention CF-PTA* and *Gesture recognition CF-GR,* see deliverable 7.1.1 for a detailed explanation of the scientific relevance of each function.

Hardware:
The experiment will be implemented on EPFL experimental set-up. The functionality of the robot will, however, be the result of a joint collaboration across EPFL, UH, LAAS and VUB. The experimental set-up for this experiment consists in a humanoid robot HOAP-2 from Fujitsu, manipulating simple colored objects, see Figure 1. Only the 11 degrees of freedom of the torso of the robot are used for the experiment.

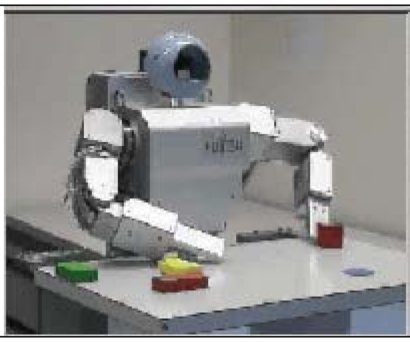

Figure 1: HOAP interacting with objects

The demonstrations are conducted by a human demonstrator. The kinematics of the demonstrator's motion are recorded using a wearable 3D motion tracking system from Xsens, see Figure 2. The system can record the motion of 11 degrees of freedom of the torso at the rate of 100 Hz with a precision of 1 degree. An openGL rendering of the motion allows one to check in real time the correctness of the reconstruction.

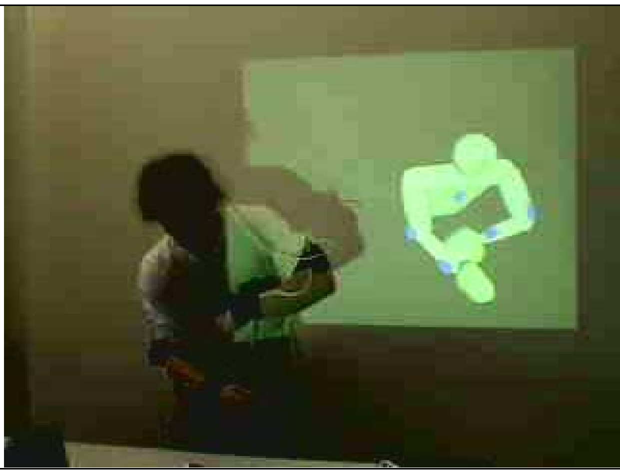

Figure 2: Motion-tracking

Motion of the colored objects are tracked through stereovision, using a pair of fixed camera, see Figure 2. The system can record up to 6 colored objects at a frame rate of 15 Hz with a precision of 10 mm.

Script 2: Learning Tasks "Serving a guest"

The scenario stresses the long-life learning abilities of the robot companion robot's ability, as well as its ability to learn context-based knowledge. It shows how the robot can build knowledge incrementally, from learning skills to learning complex sequential tasks. The script illustrates a situation in which the robot learns to perform a series of manipulation on complex object, involving specific gestures applied on specific objects (skills) in specific contexts. In order to achieve this, the robot makes use of its learning abilities to recognize complex objects, to recognize location and to detect and reproduce user's gestures.

Relation to Cogniron Functions:
This script will show the following Cogniron functions: CF-GR, CF-GR, CF-TBP, CF-LCT and CF-ACT, see deliverable 7.1.1 for a detailed explanation of the scientific relevance of each function.

Hardware:

The set-up for this experiment will be built in cooperation between UniKarl and IPA, using IPA care-o-bot robot and UniKarl set-up for detecting and recognizing human gestures. The set-up involves the following objects: a cup coffee, a plate, a box of biscuits, a bottle of water, a glass, a book and maybe other objects which can disturb the task execution of the robot. The robot is equipped with at least one manipulator arm and is mobile. There are four pieces of furniture: a couch where the human sits at, a table which has to be laid out, a book-shelf containing books, and a cupboard which contains dishes.

Different sensors (see Figure 4) are used for observation of the human demonstrator (see [5]). For observation of the actions performed by a human demonstrator with his hands, data gloves (Cyberglove, Immersion) are used for both hands. Each data glove has 22 degrees of freedom and is able to track the finger motion at 30Hz. On the back of each data glove, magnetic field position and orientation sensors are mounted for tracking of the hand's trajectories. The magnetic field tracker (Flock of Birds, Ascension) has an operational range of approximately 2.5 meters radius and its accuracy varies with the distance between emitter and sensor. The average precision is ~5cm. Object detection and tracking is done with two stereo cameras (videre design) mounted on pan tilt units.

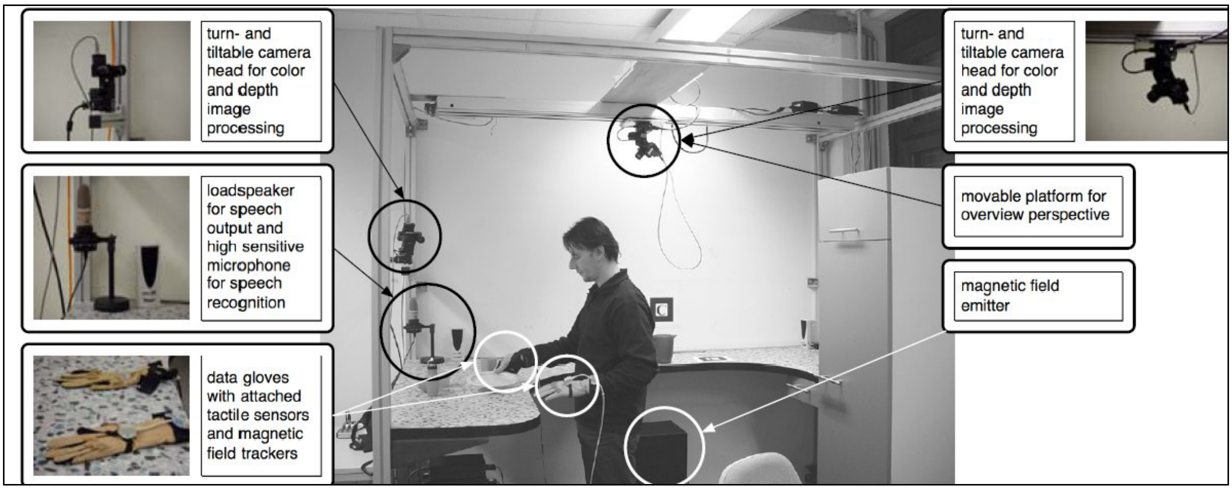

Figure 4: Sensor setting for PbD

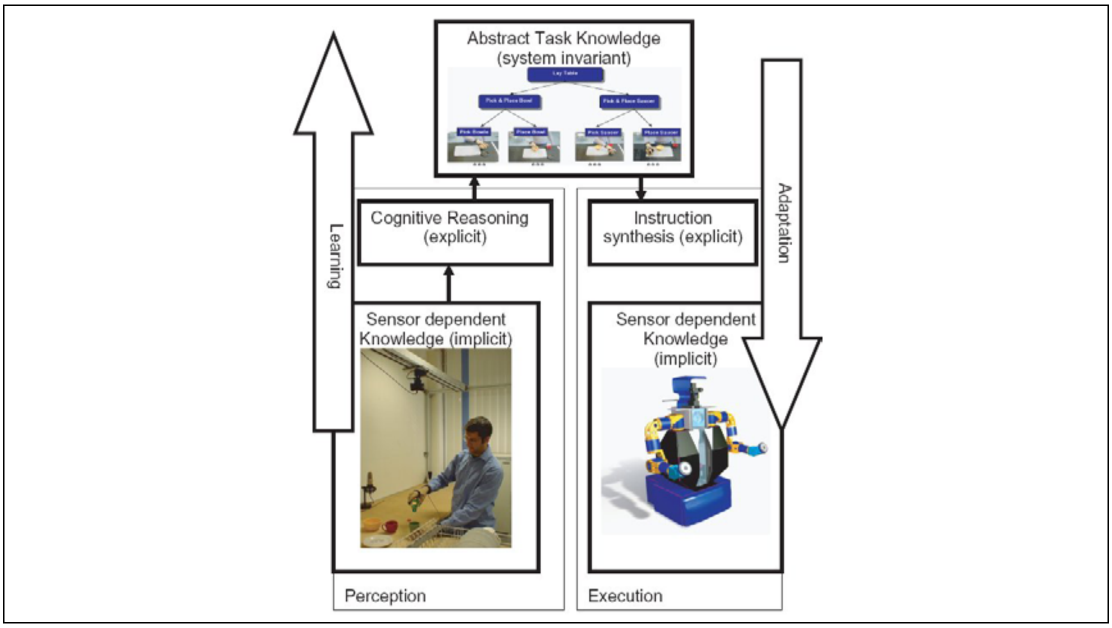

Figure 5: Knowledge representation for PbD

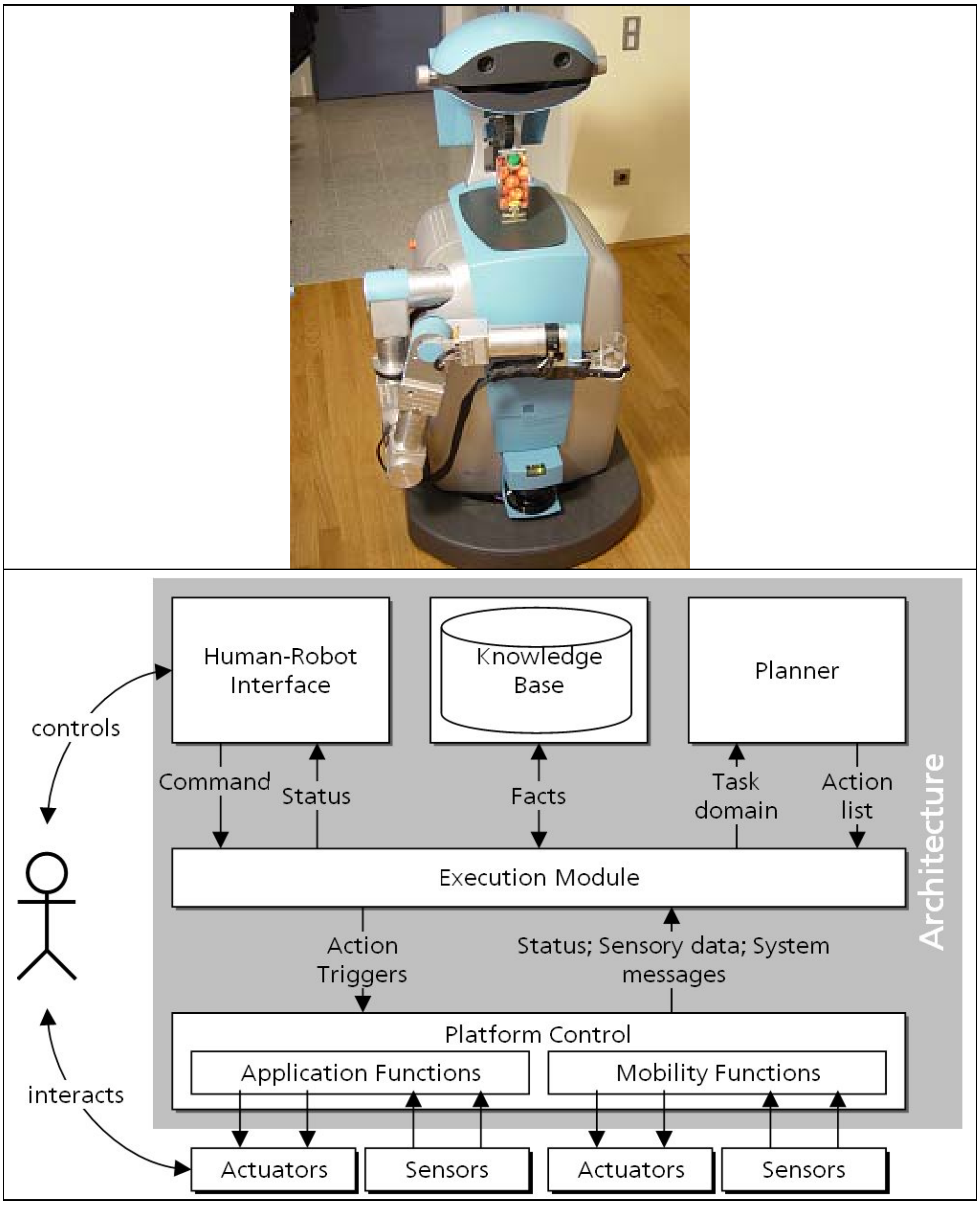

Figure 6: The Care-O-bot II (top) and its control architecture (bottom)

The PbD Process

Here is a brief summary of how complex motion from user demonstration are extracted (see [5,6] for a complete description of the underlying architecture, as well as deliverable D.4.3.1), which is also shown in Figure 5.

- Sensor systems are used for observing the users movements and actions. Also important changes like object positions and constraints in the environment can be detected. The sensor efficiency might be improved by allowing the user to comment his actions.
- During the next phase relevant operations or environment states based on the sensor data are extracted. This process is called segmentation. Segmentation can be performed online during the observation process or offline based on recorded data. Here, the system's performance can be improved significantly by asking the user whether decisions made by the system are right or wrong. This is also important to reduce sensor noise.

- Within the interpretation phase the segmented user demonstration is mapped to a sequence of symbols. These symbols contain information about the action (e.g. type of grasp, trajectory type) as well as important data from the sensor readings as forces, used for grasping, etc.
- Abstraction from the given demonstration for representing the task solution as general as possible. Generalization of the obtained operators includes further advice by the user. Spontaneous and not goal oriented motions may be identified and filtered in this phase.
- Transfer of the internal knowledge representation to the target system. As input serves the generated task solution knowledge from the previous phase. Additionally background knowledge about the kinematic structure of the target system is required.
- In the simulation step the generated robot program is tested against it's applicability in the execution environment. It is also desirable to allow the user to confirm correctness to avoid dangerous situations in the execution case.
- During execution success and failure can serve for modifications on the current mapping strategy (e.g. if a picked work piece slips out of the robot's gripper, higher grasping forces could be selected).
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2 Future work

All the experimental tools required for this experiment have by now been developed and fully tested and documented. Preliminary experiments enabling the robot to track and move objects have been conducted, that demonstrate the validity of controllers enabling the robot to track, recognize and reconstruct human motion (as part of script 1). For a complete scientific report on these capacities, the reader must report top deliverables D.4.1.1 and D.4.2.1, as well as to the peer-reviewed publications [2,3].

Future work will conduct full-fledge experiments involved several demonstrations of objects manipulation with different constraints (script1) and in different contexts (script2). As the complexity of the related Cogniron function will increase, following separate work of related research activities (RA), these will be integrated and demonstrated in KE3. It is important to stress once again that the experiment and its associated scripts have for principal goal to ensure constant sharing of information concerning scientific progresses of the related CF among the involved partners. This will continue to be done through regular meetings. In addition, dedicated visits of partners to the two institutions (EPFL and IPA) responsible to provide the hardware of the experiments will continue to be done. For instance, a visit by Aris Allissandrakis from UH to EPFL in May 2004 set the stage of the EPFL-UH collaboration toward the script 1. In turn, a visit by Sylvain Calinon from EPFL to UH, that will be held in April 2005, will concretize the collaboration. Similarly, two visits between UniKarl and IPA as participants have occurred this year and the schedule of visits for the upcoming year is currently being set-up.

3 References

3.1 Applicable documents

[1] Deliverable D7.1.1 (Specification Document)

3.2 References

[2] Calinon, G., Billard, A. (2005): Learning of Gestures by Imitation in a Humanoid Robot. In: Dautenhahn, K. and Nehaniv, C.L. (eds.). Imitation and Social Learning in Robots, Humans and Animals: Behavioural, Social and Communicative Dimensions. Cambridge University Press. To appear.

[3] Calinon, G., Billard, A.(2005): Goal-Directed Imitation in a Humanoid Robot. In: IEEE International Conference on Robotics and Automation (ICRA 2005). Barcelona. April 2005.

[4] Calinon, G., Billard, A.: Stochastic Gesture Production and Recognition Model for a Humanoid Robot. In: Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems.

[5] M. Ehrenmann, R. Zöllner, O. Rogalla, S. Vacek and R. Dillmann, "Observation in Programming by Demonstration: Training and Execution Environment", Third IEEE International Conference on Humanoid Robots, October 2003, Karlsruhe

[6] R. Dillmann, R. Zöllner, M. Ehrenmann, O. Rogalla, "Interactive Natural Programming of Robots: Introductory Overview", DREH 2002