3rd HAND
FP7-ICT-2013-10-610878
1 October 2013 (48months)

D5.1: Scientific Results on the Robot Platform Setup and Maintenance an the Scenario 1

TUDa

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Due date of deliverable:	Y12
Actual submission date:	some time
Lead Partner:	TUDa
Partners:	TUDa, UIBK, USTT
Revision:	draft
Dissemination level:	PU

This deliverable reports progress on the platform setup, integration among partners, and development of the software. This deliverable also discusses the planned and achieved goals during the first year and provides links to videos of interest.

Executive Summary

This report presents the setup of the vision hardware at TU-Darmstad and initial implementation of the fundamental software architecture to which all partners integrate. Part of the results of the first year implementation of the framework has been published in [LKPM14a] and also disseminated in a workshop [LKPM14b]. The initial results of trajectory optimization library designed by USTT using models created at TU-Darmstadt are also reported.

Role of Platform Setup and Contribution to the 3rdHand Scenario

This deliverable sets the foundations of the hardware and software to be used throughout the project. This deliverable also accounts for the initial libraries that allow for the modeling, simulation, motion planning, trajectory optimization, and communication of the experimental platform.

1 Tasks, objectives, results

1.1 Planned work

During the initial year of the project the principal topics to be addressed are described as follows

1. Setup of the vision system hardware, specified by UIBK, on the dual-arm robot setup in TUDa
2. Definition of the commond middleware to which all teams will receive and transmit messages followed by the protocol and definition of messages
3. Implementation of a modular architecture that allows for the incremental and scalable integration of partner modules. The architecture must be broad enough to account for the processing and transmission of sensor data (e.g. vision and motion capture), high and low-level commands, and must also integrate third-part software (e.g. Matlab).
4. The organization of periodic integration meetings where the involved partners integrate their latest work
5. The design of a human-robot interface that allows for natural human instruction and interpretation of the system states

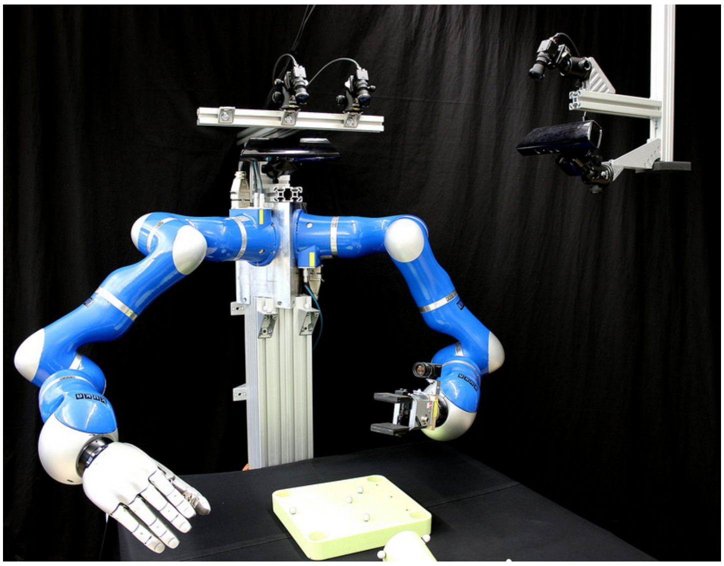

Figure 1: The experimental platform setup consisting of two KUKA lightweight arms, two DLR-HIT five-fingered hands, two Kinect cameras, four CMOS sensor cameras, and one motion capture system (the latter not visible in the picture).

1.2 Actual work performed

Figure 1 shows a picture of the experimental setup after with the addition of the cameras. For details on the implementation and algorithms developed for pose estimation of the objects in the scene, please refer to deliverable D2.1.

During the first year it was decided that all participants will interface their modules as packages of the Robot Operating System (ROS), thus allowing for modularity and scalability. This decision immediately lead to the specification of messages and implementation of a Unified Robot Description Format (URDF) model of robots available at different participant institutions. The current model for the experimental platforma at TU-Darmstadt (Darias) can be used to visualize, in real-time, the state of the actual robot using rviz. The same model is also implemented in the Gazebo simulator and MoveIt! packages for dynamic simulation and off-the-shelf motion planning, respectively. The model was made available to all team members.

As a part of work for the first year, partners of the project integrated data from the recordings and motion synthesis in two simulated scenarios. The constraints, described in detail in D3.1, were obtained by optitrack system (INRIA) and magnetic tracking system (USTT). The robot model was provided by TUDa. Two scenarios were recorded: (1) assembling an IKEA

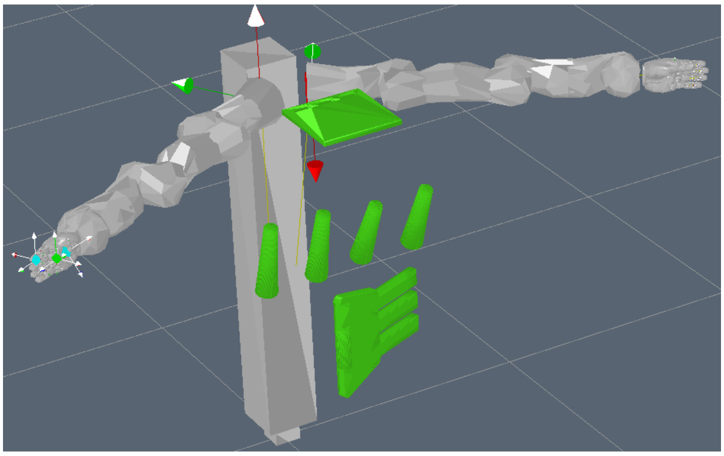

Figure 2: Darias robot model in Open Robot Simulator developed in USTT. The simulator is capable of motion planning via trajectory optimization using e.g. Gauss-Newton method with adaptive step-size.

chair (see Figure 2 for illustration) and (2) assembling a toolbox. The resulting respective motions motions can be seen in the following videos
`http://ipvs.informatik.uni-stuttgart.de/mlr/dmitry/videos/TOOLBOX.mp4`
`http://ipvs.informatik.uni-stuttgart.de/mlr/dmitry/videos/IKEA_CHAIR.mp4`

The system architecture that manages the ROS nodes and also the communication among other programs such as Matlab and proprietary motion capture software has been developed under the name Robcom. The basic structure of Robcom is shown in Figure 3(a). During the first year, to test the capabitilites of the software architecture a complex task of sequencing and encoding several demonstrations in the form of Dynamic Movement Primitives (DMPs) was published in [LKPM14a]. A broader version of this work, which emphasizes the 3rdHand robot project as a whole, was also presented at the 1st International Workshop on Intelligent Robot Assistants workshop [LKPM14b].

In regards to planned item 1.1.5 the original proposal suggested the implementation of a small set of verbal instructions. We have implemented those instruction in one-way: from the robot to the human, by using text to speech packages. This allows the robot to update the human coworker on the system status and give him instructions when necessary, for example, when a new demonstration is needed or when the robot needs the human to back off. Currently, commands from the human to the robot are made via a smartphone/tablet application designed in-house (see Figure 3(b)). We have opted for such an interface due to the flexibility of changing the interface and ease of operation while avoiding misrecognition of human commands given by

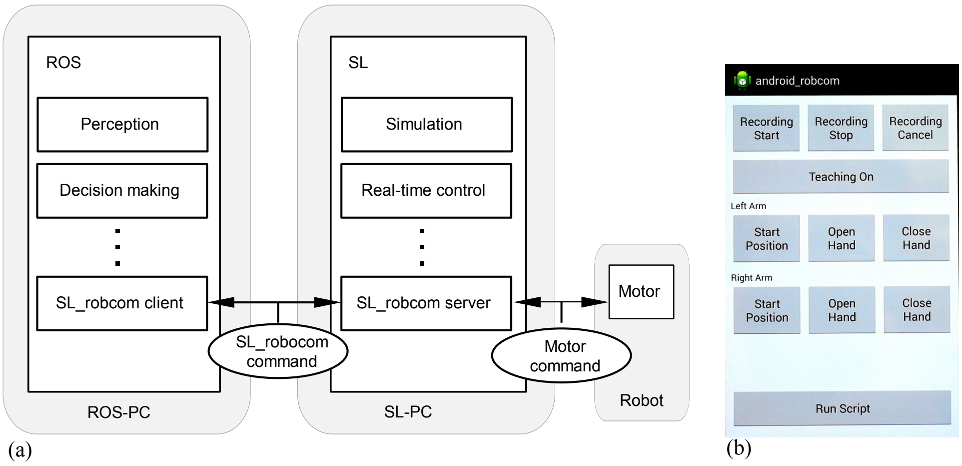

Figure 3: (a) Simplified illustration of the system architecture applied in this work named robcom. (b) The interface developed as an application for smartphone/tablet as part of robcom to facilitate the use of the robot.

voice.

Integration meetings took place in the following days

- 11-15 August, 2014. Vision-robot pre-integration
  Specification of cameras and design and installation of structural frames for camera setup
- 25-29 August, 2014. UIBK-TUDa integration in TU-Darmstadt
  Setup of cameras and vision computer. Initial testings of pose estimation for robot grasping.
- 1-12 September, 2014. All partners integration in TU-Darmstadt
  3rdHand framework update with the integration of latest achievements among all partners.
- 15-19 September, 2014. UIBK-TUDa in TU-Darmstadt
  Experiments to evaluate the vison-robot integration, leading to the submission of the publication [ESS+15].

References

[ESS+15] Ozgur Erkent, Dadhichi Shukla, Sebastian Stabinger, Rudolf Lioutikov, and Justus Piater. Probabilistic, appearance-based object detection and pose estimation of textureless objects for robot manipulation. In *Submitted to: Proceedings of 2015 IEEE*

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[LKPM14a] R. Lioutikov, O. Kroemer, J. Peters, and G. Maeda. Learning manipulation by sequencing motor primitives with a two-armed robot. In *Proceedings of the 13th International Conference on Intelligent Autonomous Systems (IAS)*, 2014.

[LKPM14b] R. Lioutikov, O. Kroemer, J. Peters, and G Maeda. Towards a third hand. In *1st International Workshop on Intelligent Robot Assistants*, 2014.