CogLaboration

Collaborative Project

FP7 – 287888

D5.60 -- Complete integration report

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Abstract

The purpose of this deliverable is to demonstrate that the main components developed within the CogLaboration project have been deployed onto the robotic experimental setup, and also providing the first validation before the complete evaluation realized in the context of the Work Package 6.

This document complements the information already provided in some recent related deliverables. D5.12 provided a description of the whole CogLaboration software architecture. D5.51 focused more on the description of the hardware devices that have been combined to build the CogLaboration prototype. In this document, we will demonstrate the good software and hardware integration of all these elements by illustrating some example of use of the prototype. Several object exchanges with a human participant are presented highlighting as much as possible the impact of the different modules being involved in the decision making of the robotic platform.

[End of abstract]

Executive summary

This deliverable is provided in conclusion of Work Package 5, dedicated to the software and hardware integration of the CogLaboration project. Considering the various previous deliverables describing either the overall software architecture or the hardware components put together to build the prototype, this document demonstrates the good component integration by showing and describing some object exchanges in between the robot and a human partner.

In each experiment presented, the articular and Cartesian trajectory of the robotic system is presented, together with the trajectory of the human hand and the object tracked (when relevant). The related graphics are augmented with the main events used to orchestrate the successive operations of the robot. Considering that these different triggers are related to different software components from the robotic system (perception, hand sensors, hand actions,…), such description is demonstrating a good collaboration in between the different agents involved in the CogLaboration prototype.

The current document describes four consecutive exchanges in between the two partners. An extension of the document will illustrate the good interaction in other situations to cover all the capabilities of the system.

Document Information

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21/11/2014	0.1	Remazeilles	Template preparation & outline definition,
27/11/2014	0.2	Remazeilles	First section of experimentations
28/11/2014	0.3	Remazeilles	Complete draft ready for review
29/11/2014	0.4	Burgin	First revision
30/11/2014	0.5	Remazeilles	Integration of revision, extension of some figures.

Table of Contents

1 Introduction

This deliverables concludes the work realized within the Work Package 5 that was dedicated to the integration of the software and hardware components developed during the CogLaboration project lifetime. Several previously produced documents provide some indications of the coordinated system development and integration. In particular, deliverable D5.12 provides a global overview of the complete software architecture, gathering interfaces and specifications designed and presented in more details in the related Work Packages. Deliverable D5.51 was written to describe the different hardware components either designed during the project or at least combined to get the appropriate robotic prototype. To illustrate the integration of the different hardware components, some specific demonstrations of motions were included in which the robotic system was reaching and grasping an object put onto a vertical object board. Such actions already demonstrate a certain level of coordination and communication in between the different perception and control layers: the object pose with respect to the robot camera though the perception layers developed in WP3, the control of the arm motion towards the grasping posture was also based on a DMP-based control, like the control mechanism developed in WP4, and the object acquisition demonstrates on its own the capacity to control autonomously the robotic hand, thanks to the related developments in WP4 and WP5.

With the objective of reducing the overlap with the deliverables already published, while demonstrating still an improvement towards the design of a robotic companion with manipulation and physical interaction capabilities, this document describes different experiments performed using the system, focusing on the object exchange between the robotic arm and a human partner. In the context of WP6, a systematic evaluation of the system is being prepared, considering several human partners to which some motions variations will be proposed to demonstrate the robotic adjustment capability. To complete the picture, the present document will detail some specific but representative object exchanges situations, highlighting and demonstrating the information transmission between the main components, as well as the main events detected and which impact significantly onto the robotic behaviour and its motion strategies.

Similarly to the modus operandi used for the evaluations in WP6, the experiments presented all start in the condition that the system is ready to perform an object exchange, and is thus waiting for the appropriate trigger to start its motion. The exchange direction, either from the robot to the human (R→H) or from the Human to the robot (H→R) will be indicated for each experience described. We thus suppose that, in the R→H case, the object is already held by the robotic hand, and that for the H→R direction, the object of interest is known by the robotic system and is already held by the human partner.

The different experiments that we propose to detail here aim to illustrate different aspects of the robotic controller developed within CogLaboration. To name the main components, we can mention:

- Capability to learn the most appropriate exchange site over many interactions.
- Capability of online adjustment of the robot motions according to the motions of the human partner
- Capability to handle different objects and grasping or delivery modes.
- Capability to adjust the handover strategies according to the human partner actions and preferences
- Capability to handle transport constraints in relation with the objects considered
- Capability to handle some object symmetries to adjust correctly the relative grasping and delivery poses according to the perception of the object.

All these aspects will be demonstrated when appropriate in the experimentations described in the following section.

2 Experimentation

Figure 1 illustrates the typical experimentation configuration. The main components involved in the interaction process are described below with reference to this figure:

- The system perception is performed using the image and depth information acquired by the Kinect camera pointing towards the human. From the vision flow, the human motion start and stop events are detected and used to trigger the actions of the robot. In H→R exchanges, the hand tracking is used to seed the moving object pose estimation. Note that in the current implementation, we decided to implement a contingency action that consisted of using the object sensor developed by RUR to get the object orientation. This enabled us to get a more stable, precise and faster estimation of the object pose.
- The robotic arm equipped with the Prensilia anthropomorphic hand is naturally one of the most critical element of the robotic prototype. The cognitive layers permit the definition of an appropriate plan to go and perform the object handover. This plan is monitored online, and changed if the human actions require readjusting the initial robot handover strategy.
- Even if not explicitly visible on the picture, the object grasping database has also a critical contribution, since it is providing the controller with the relevant respective poses (from the robotic hand to the object or to the human hand) to appropriately position the robot hand, together with additional information defining the handover. Note that, in addition to these collections of data, the database is also used to store the current human interactions preferences, in order to adapt the motion of the robot to the human intentions as much as possible, considering the exchange site spatial location and the handover modes to be used with each object.

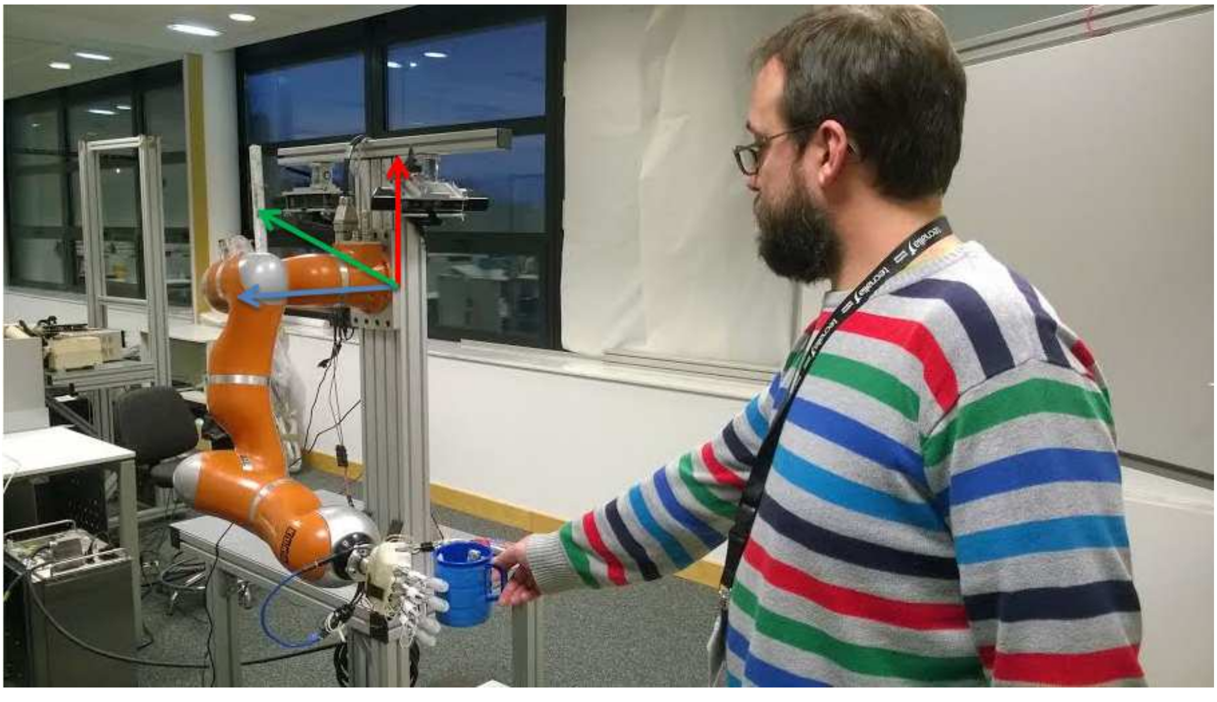

Figure 1: Typical exchange configuration. The RGB frame presented on the image defines the robotic base frame. All the following plots will be done using this frame as reference to express Cartesian positions.

2.1 Experimentation 1: nominal object exchange

This section presents four consecutive exchanges of the object ¨Mug¨ between the human partner and the robot. On these plots, the blue lines are the Cartesian location of the hand of the human partner and the red lines are the Cartesian position of the robot hand effector. When the exchange is from the human to the robot, the object location is also presented in purple on the graphics. The three plots are respectively related to the X, Y and Z axes. The reference frame has been chosen to be the arm base frame, as shown on Figure 1. Figure 2 presents the first exchange performed, and Figure 3 presents the four consecutive exchanges done. Figure 4 presents the evolution of the robotic arm joint values during these four exchanges.

The main events describing the evolution of the exchange procedure are presented through the vertical lines. The ones displayed are respectively related to the followings actions:

- **Op_start**: the robotic system is informed about the exchange intent, by indicating the object of interest. The unique object identifier is provided through the operator interface. It permits (i) the consultation of the object database to obtain the handover properties of the object, and (ii) the specification to the perception module (for human to robot exchange) the object to be tracked within the human hand. Note that on this experiment, the first exchange was a human to robot one (and thus the following ones were respectively R→H, H→R, and R→H). The system is then expecting a motion trigger to launch the motion of the robot.
- **Op_move**: the motion is triggered by monitoring the location of the human hand. Once moving away from the rest position, it is considered that the person is intending to start the exchange. This is used to trigger the start of the robot motion. At that moment, the robot moves towards the learned exchange site. In R→H exchange, while the robot starts its motion, the hand gets pre-shaped according to the grasping strategy provided by the database.
- **Op_static**: the human motion monitoring has detected that the human has reached a static configuration, likely to be the desired exchange location. At that moment, the observed location is used to update the target position of the robot for the current interaction. When the exchange location learning is activated (not the case here), this location can be stored to get an a priori estimation of the human preferred exchange site.
- **Op_replan**: To avoid reaching the robotic arm joint velocity and acceleration limits, soft boundaries are defined, and the DMP output is monitored online to make sure they are respected. When these bounds get violated, the high level controller updates the DMP plan to get a new path definition that can be safely achieved by the robot (i.e. respecting the velocities and accelerations limits defined).
- **Op_contact:** this flag is raised when the handover can start, i.e. when the human and the robot are entering into contact. Currently, this is monitored using the force sensors from the arm, as well as the contact sensors embedded into the robotic hand fingers and palm. Depending on the exchange direction, this causes the hand closure (to grasp the object) or opening (to release the object).
- **Op_rest:** the handover is finished. The robot is then requested to go back to a rest position,
- **Op_done:** the robot has reached the rest configuration, and is now waiting for the next exchange to be requested.

Several elements can be highlighted from these figures:

- The estimation of the human hand location can be considered as noisy. This is mainly due to the segmentation techniques, based on colour that may not always completely detect the hand in the sensor point cloud. The extraction of the centroid point of the segmented area can thus oscillate as observed. Another potential source of erroneous tracking can be the close vicinity to the robotic hand as the handover. To reduce the impact of this situation, the goal location used to guide the robot is set static when the distance hand effector-human hand (or object of interest) gets lower than a defined threshold.
- The human person is moving much faster than the robot. In less than a second the human partner has reached its desired exchange location, while the robot needs around 3 to 4 seconds. Moving faster the robot could improve the synchronization of the two agents. Nevertheless, since the two hands (robotic and human) would reach the exchange site at the same time, the perception layer would need to be able to distinguish them. The current perception layer does not permit to do so. For these reasons, a reduced robot velocity was chosen.
- The motion of the robot is smooth during the whole exchange, even though the input from the hand tracking module presents some noise (in between the op_move and op_static events). This

smoothness results from the DMP model that acts as a low-pass filter between its input (hand/object observed location), and its output (the robot motion command).

- In this first experiment, the exchange site learning is not active (and the default exchange site was at about 30 cm from the effective one, to enforce a plan update. The position change can be implicitly guessed from the joint variation change around the op_replan event on Figure 4). When the person reaches the desired exchange location, the controller's goal position is updated with this information.
- Due to the significant difference of position, the DMP generated large velocities that violated the defined soft boundaries. As previously mentioned the low-level controller detects such situation and request to the high-level layer an update of the DMP plan, enabling it to cope with the new goal while respecting the maximum velocities/accelerations. As can be seen on the drawing, this operation happens seamlessly (the change is not visually perceivable, and can neither be observed on the drawing presented here). Note that if the exchange site learning is activated, such aspect should only occur in the first exchange, when the preference of the human partner is not known. Later on, the a priori estimation of the exchange location should be sufficiently close to the real one to avoid such replanning.

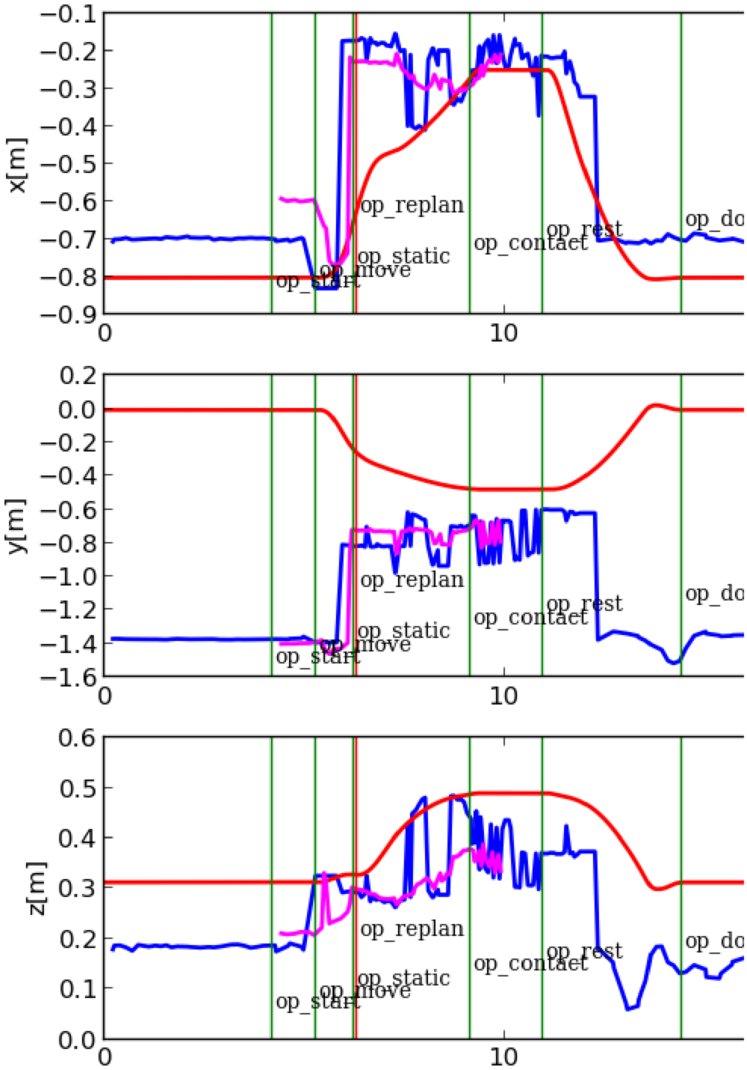

Figure 2. Basic exchange, zoom onto the first exchange of Figure 3 (Blue: human hand position, Purple: object location, Red: Robotic arm location). Green lines refer to specific events identified by the system during the interaction.

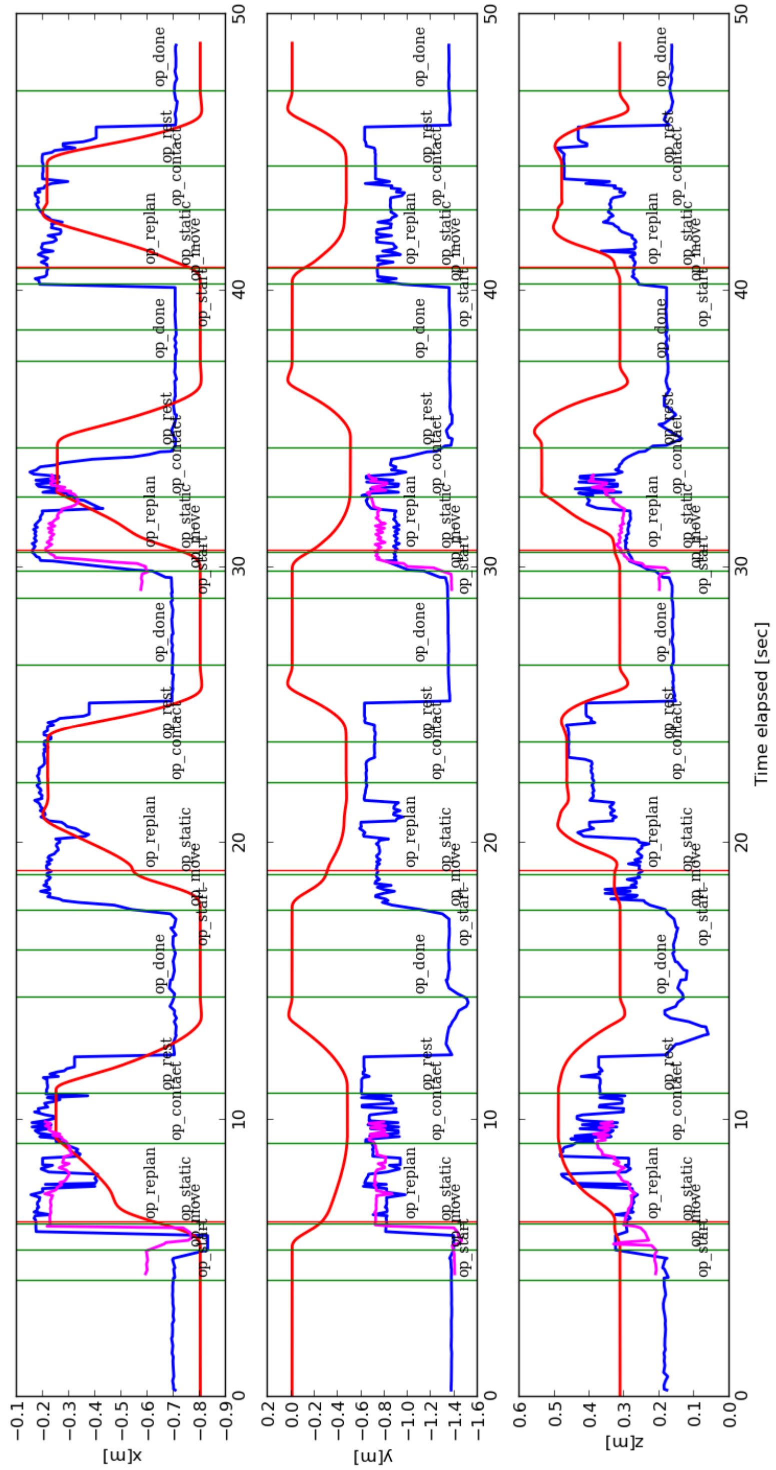

Figure 3: Four consecutive human robot interactions (starting with a Human→ Robot Exchange). The blue line is the human hand position, the red one the robotic arm end effector. On Human→Robot exchanges, the position estimation of the object is presented in purple. Vertical lines are related to specific events used internally to orchestrate the different actions of the robot.

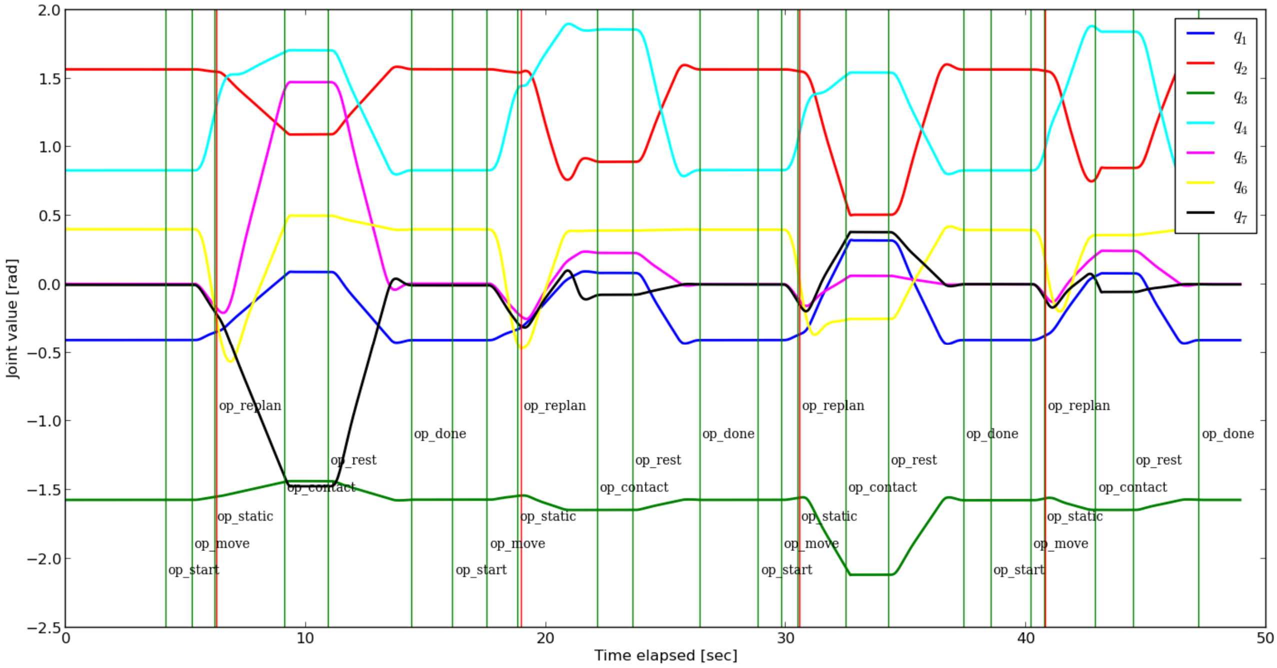

Figure 4. Evolution of the joint values of the robotic arm during the basic exchange

In addition to this first experiments, that already demonstrate a satisfactory coordination and collaboration in between the different component developed in CogLaboration project, we are planning to extend this document with the following experiments:

- Activation of the exchange site learning along interaction
- Adjustment of the robot handover strategy to the object orientation (when held by the human partner)
- Adjustment of the robot handover strategy to the human hand posture
- Capability to handle object transport constraint.

3 Conclusions

This document has illustrated the integration of the different components of the CogLaboration project onto successive object exchanges between the human partner and the robotic system. These exchanges have been described through the display of the Cartesian location over time of the different agents during the exchanges. The human hand and the object (during H→R exchanges) are estimated by the perception module. The orientation of the object is furthermore obtained from the RUR sensor device. The trajectory of the robot end effector is the output of the CogLaboration system, bringing the robotic hand towards the exchange site for performing the object handover with the human partner.

Other experiments will be provided to extend that document and properly illustrate the other capabilities of the robotic prototype of CogLaboration.