Building Low-Cost Mobile Manipulation Platform for RoCKIn@home Competition

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***Abstract*—MYRABot platform has been developed in our lab for researching tasks during the last two years. On the one hand this robot has been designed as a socially assistive robot, on the other hand, it has to be economically affordable. We also think that this platform can be used in other environments as robot competitions. For this reason we have decided to adapt the platform for one of them, choosing the RoCKIn challenge. This challenge presents different environments for robot testing and knowledge transfers between researchers and companies. This paper addresses the steps that we have followed to set up the robot for the RoCKIn @home challenge. We present the robot development from the initial model until the actual platform, showing how the concept of low cost platform prevails in our development.**

***Index Terms*—Low-cost robot, Autonomous robot, Service robot, Robot challenges, RoCKIn@home**

I. INTRODUCTION

THE mobile robots development can be faced from different points of view, usually the hardware and software limitations related with the robot task and its environment. Globally we can define hardware restrictions as size or weight for but also locally the components definition have to be defined: what kind of vision sensors (according the range, field of view), actuators (maximum torques, encoders,...) or controllers (CAN-bus, GPIO available, ...) As software restrictions the researcher has to address the operative systems (real-time oriented, distributed,...), programming languages, or finally the control architecture (reactive, deliberative, hybrid, ad-hoc) The motivation for choosing one or the other is related with the task to be performed and the environment restrictions. But what happens when you add an economical restriction to this concepts? We present in this paper our perspective for achieving a platform for human robot interaction with economical restrictions. The goal of this platform is to take part in robot competitions and challenges as RoCKIn @home.

RoCKIn challenge was unveiled in 2013 with the aim to define a test bed for robotics in two well define environments, @home and @work. The @home environment focus the efforts in assistive platforms and how they can help in different assistance tasks. The @work challenge is industrial-oriented, and aims to help the operators in their jobs.

Along this paper the set up of our platform for RoCKIn competition is shown. Section II shows the robots that belongs to the RoCKIn@home challenge. Section III shows the platform evolution until the RoCKIn challenge. The section IV discuss the hardware components selected for our platform with the economical limitation of 3000 euros. The section V shows the software components, the software that manages the robot by one side and the virtualization environment by the other. The section VII presents the experiments performed with the platform in the last RoCKIn camp, and finally in section VIII the conclusions about the robot set up and the first RoCKIn experience are presented.

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II. ROCKIN CHALLENGE

The RoCKIn challenge is an European competition to be developed between 2013 and 2015. It presents a new system of competition divided in two phases each year, camp and competition. The camp lasts just one week and there the people attending different seminars related with robotics technologies. An advantage of this challenge versus other challenges is that people without robot can go to the camp and can test their algorithms using an available platform. The aim of RoCKIn challenge is to measure all the different components of robots competitions: platforms, algorithms, ...

Current version of our platform was designed to this competition. In this section we are going to compare it with other robots entering this competition in the 2014 camp. Figure 1 shows them, these platforms are different but fulfill three basic premises: the robot can be deployed in a non-modified home (with some restrictions), the robot can navigate at home and the robot has one arm (at least) for manipulation.

The Care-O-Bot platform [9] from Fraunhofer IPA was developed as a service robot, taking in account a multi-disciplinary concepts. One of their main doubts during the platform design was to make an anthropomorphic platform or a 'technomorphic' robot. This is one of the first questions that every assistive robot has to answer. We opted for the same line that this platform a 'technomorphic' solution.

The Rita robot (Reliable Interactive Table Assistant) [1] is also a platform for assistance tasks, it hasn't got an arm but like us they added it for the competition, the MICO arm from KINOVA. A coincident decision of this platform is the wood frame, we also have a wood frame but we use a 5mm of laminated wood, instead of real wood as it does, because a wood frame is too heavy. We also address other problem, the size, it is too big to be deployed in a real home although it fits in the competition environment. Anyway the RITA platform is presented as one of the most safest robots for @home environments.

The REEM platform [8] is one of the most advanced architectures available in robotics competitions. This platform has a mobile base and on top of it they have mounted two

Fig. 1. Robots in RoCKIn competition. From left to right: Care-o-Bot, RITA, REEM, Sudo, ISR-CoBot

Team	Robot Name	University or Company name	Price (euros)
n/d	Care-O-Bot	Fraunhofer (IPA) (Germany)	+100k*
Borg	RITA + MICO (kinova)	University of Groningen (Netherlands)	27,000 + MICO
n/d	REEM	Pal Robotics (Spain)	+100K*
Borg	Sudo	University of Groningen (Netherlands)	Pioneer (5k) + MICO
SocRob	ISR-CoBot	IST (Portugal)	tens of thousands
Watermelon	MYRABot	University of León (Spain)	2500€

TABLE I
TEAMS IN ROCKIN CAMP 2014

arms with hands, a torso with a display, and head with a mask face in an anthropomorphic way. This platform has been tested during the last years, and now it is possible to see the skills in the competitions. The platform is managed with the ROS framework in the same way that the other teams does.

The Sudo platform [4] is multicomponent platform made by the University of Groningen. They have been researching in HRI platforms during the last years and taking part in many RoboCup @home competitions. The main components of this platform are a Pioneer base, a full metallic frame and a NAO robot for all the interaction process. For this camp, they changed the Nao robot for the MICO arm from KINOVA, the reason is that although the Nao robot is suitable for robot interaction experiences, the Nao hand are not able to do a full manipulation of real objects as for instance bricks or cans. The design of this platform is similar to our solution, a frame able to integrate all the components needed for the competition.

Finally the ISR-CoBot platform from Instituto Superior Técnico in Portugal. Their robot uses a platform developed by Carnegie Mellon university [11], [12]. They added extra cameras to the original platform and also a Katana arm from Neuronics AG to fulfill the competition requirements. This platform has an architecture developed in ROS and also they have a simulation model based in Gazebo, as REEM, Care-o-Bot or as we do. This robot has a display on top of the frame as is presented in our platform but they are not able to modify the height.

An outline of robots presented here is shown in table I. The table shows the Team Name (not defined means that the organization, the university or a company offer it to whatever other team for testing their algorithms), Robot Name, University or Company name and the price. The price shown in last column is estimated but it allows us to make a quickly comparison.

III. MYRABOT EVOLUTION

This section describes the MYRABot platform evolution. It was started in 2012, and the las prototype was shown in RoCKIn Camp 2014. This evolution can be seen in figure 3. At the beginning the platform was designed for elderly assistive tasks with two concepts in mind: offers a telepresence system and and for helping in daily tasks with augmented reality. The first will allow the elderly people to keep in touch with their family and friends. The augmented reality concept was introduced in our platform for offering a solution to improve the drug dose control in the elderly.

We started this research thinking that this solution could be deployed in a low cost platform as Turtlebot, but after a few experiences [2] we saw that the platform design was not the adequate for the interaction, the height of the solution and the non-display morphology were a handicap for interacting with humans. Since this moment we decided to develop a new platform morphologically talking, for improving the interaction experience but supported in the idea of low cost initiated by TurtleBot.

The first step was to select the robotic base, we should change, we should buy a new one or we should build a new one. Due to our previous experience we decided to use the same base iCreate, but it was not available in our country, so we decide to change to Roomba whose behavior and development is similar to iCreate, and also it has a feasible price. Figure 2 shows the real turtlebot and our first prototype (Roomba+computer+controller). The main problem related with the new base was the integration with the external sensors. iCreate has a parallel port ready for connecting other sensors, as for instance the kinect and also for power supply. In our case we use a hacked USB to serial interface for controlling the base and for getting the kinect power.

We performed two HRI experiments with a small group of 5 individuals to evaluate our first design (the model I in figure 3). We conclude in these experiences that the platform morphology designed was not the best solution for HRI. For instance we were not able to make a good interaction experience due to display position (this conclusion can also be found in literature [10]). For this reason we built a new frame able to change the display height and display angle, this frame is presented in the second picture of figure 3 and can be defined as model II.

From this experience we defined the main constraints in the frame development: a) the morphology, it has to be comfortable for interacting with humans and also it has to be able to integrate different sensors, we decided to build a height adjustable frame with a minimum height of 95 cm and a maximum height of 160 cm for interacting with people sitting or standing with adjustable display levelling b) the materials, it has to be easy to model, it should has low weight and it has to be mounted and unmounted easily, we chose poplar laminated wood for handling it easily in our lab and because it offers resistant to warping and shrinkage and c) the display, we need it for offering a non verbal interaction system, we already had an interactive software solution called MYRA for helping in the drug dose control and it extensively uses a display therefore we need to put in top of the robot the display to allow users the interaction with MYRA.

Our next goal after the real experiences was to add an arm to improve the interaction. We were using the AR for the interaction and an arm allow us to offer other non verbal interaction methods as: point, grasp, manipulation,... . The model III shown in figure 3 was the new version of our robot.

Finally the model IV (figure 3) is an adapted version of our platform to fulfill the requirements of the RoboCup competition. The main features in this evolution: the button box with robot start-stop button, Roomba start-stop button and the emergency stop button. In this last phase we also arranged all the wires along the robots using plastics leads and we covered all sharp edges with wooden cases to avoid hurting people.

IV. Hardware Overview

This section describes the hardware components of MYRABot, they are enumerated in figure 4.

A. Base

The Roomba vacuum cleaner from iRobot is our mobile base (element 9 in figure 4). This is a differential drive base

Fig. 2. Turtlebot Evolution

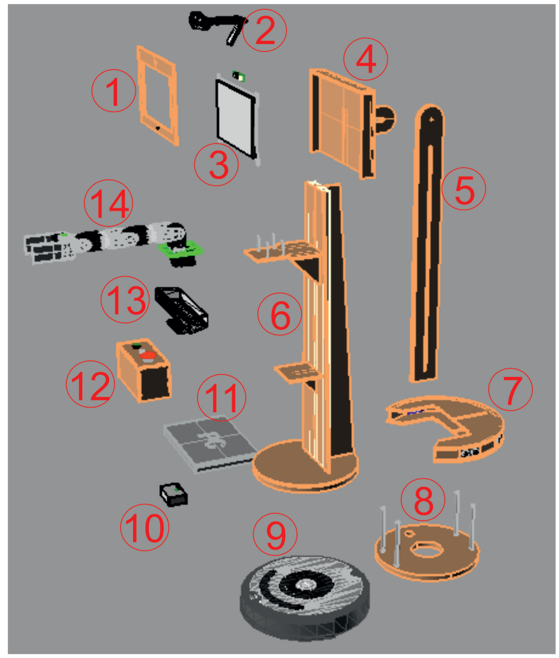

Fig. 4. MYRABot components

whose main sensors are: bumper, infrared receiver, and cliff sensors but these sensors are not enough for classical indoor robot navigation techniques, and the kinect has to be used.

The Roomba has been modified in different aspects: a) the first one is related with the frame attachment, b) the second one is related with the full battery disconnection and c) the kill switch or emergency stop and d) output connector from main brush for feeding the arm.

B. Frame

From the hardware point of view we had to choose between different materials as methacrylate, PVC or aluminum but finally we avoid them because of the price and the difficult to handle.

We chose poplar laminated wood, it is more easy to manage with common tools. The components made of wood are: a) the display case (1,4), b) the full adjustable frame with the arm and kinect supports (5,6,8), c) the range sensors case (7) and d) the button box (12).

The poplar laminated wood is a lightweight and resistant material. The main frame is mounted in a T-shaped way to improve the resistant allowing us a light frame for avoiding base overload.

We made all the development following digital fabrication and rapid prototyping techniques [6], [5] in a FabLab laboratory [7], [3].

We have developed a frame able to be adapted according the interaction experience, the reason is that during the interaction the individual position can be defined as standing, sitting, or lying. In this way we built a manually height-adjustable system to handle the display position and also a manually rotation system for the best angle visualization.

The main specs of this frame are:

- Max/min height: 1.6 m / 1.080 m

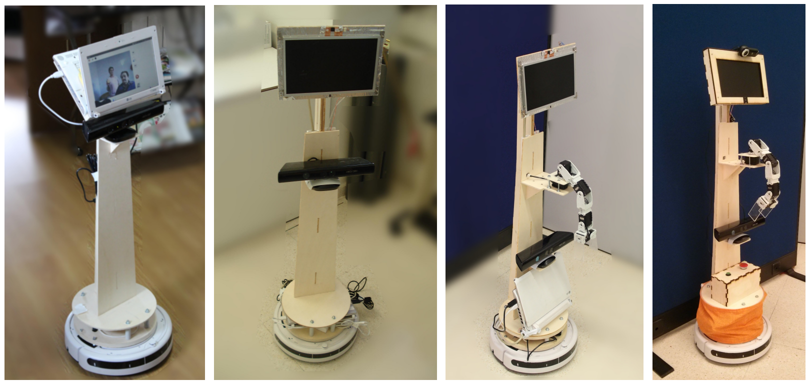

Fig. 3. MYRABot Evolution: Model I, II, III, IV

- Weight:aprox 3 kg
- Display rotation: 238 °

C. Arm

The arm (element 14 figure 4) has been built using the commercial off-the-self Bioloid educational kit and using Dynamixel AX-12 servos. We choose this option for two reasons, the low price and they can be feed using the roomba battery.

We are using 5 motors: one motor is used to control the gripper, one motor controls to yaw movements and the other three allow us to work in the same plane so we are working with a 4 DOF arm.

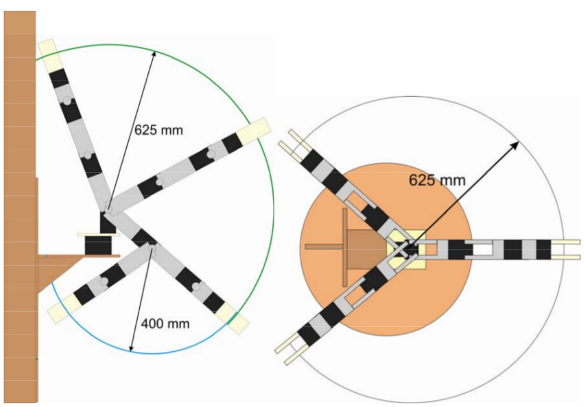

Fig. 5. Arm workspace

From the software point of view, we have developed an embedded solution for educational reasons but for challenge we developed a ROS module for a better platform integration.

D. Vision Sensors

We use two different types of vision sensors: 3D sensor and 2D image analyisis.

The primesense sensor are the Kinect mounted on the frame for navigation tasks.

The two RGB cameras are mounted on top of robot. The first is the netbook integrated camera, we have moved it on the display case. The second one is a basic USB webcam used for manipulation tasks.

The problem of this kind of sensors is related with the depth data processing. The computational cost related with RGBD sensor is high. The computational cost related with 2D cameras is feasible in our platform and allows to deploy robot behaviors fluently.

E. Dialog system

We have mounted a microphone on top of the platform as an input sensor. We have removed the netbook's integrated microphone and we have installed it within the display case. As an output system we have used the netbook's built-in speakers whose placement are the base of the platform.

F. Control and Communications

The main components of control and communications are three:

1) Netbook: It is the process unit. It mounts an Intel Atom processor with 1GB RAM
2) Arm Control: It is an Arduino MEGA 2560 REV3 board. It mounts at ATmega2560, Flash Memory 256 KB, SRAM 8 KB, EEPROM 4 KB and 16 MHz Clock.
3) Communication interface (CI) : the chip FT232RL is the main component. The FT232RL is a USB to serial UART interface. This interface is built in a Bus Powered Configuration

The communication interface (CI), element 10 in figure 4, was developed for controlling the base. This CI is a custom board developed by our group that uses the serial port features. It is connected with mini-DIN 7-pin connector to roomba and a USB connector in the PC. The key point of this interface is the modification for getting the power supply for kinect camera (12V).

V. Software Overview

We have designed all robot behaviors using ROS software development framework (Robot Operating System). ROS has had eight official distributions until now. Since 2010 ROS released two distributions per year until 2013 the reason was that ROS was developed following the Ubuntu schedule as the main development platform. For this reason we find 6 distributions in three years. But during the last two years ROS increase support to other OS distributions and in this way they changed these policies with only one distribution per year an also with a well defined relation with Ubuntu LTS.

The robot have installed the Fuerte distribution but we also use some Electric packages because some modules off-the-self were in this distribution and the integration with Fuerte was easy.

In figure 6 a high level view of ROS components integrated in the MYRABot platform are presented. We have a lot of dependencies with low ROS core packages as: *roscpp* library that provides the C++ interface for ROS; *std_msgs* package provides the primitives for all messages representation used in ROS; *geometry_msgs* that provides geometric primitives such as points, vectors, and poses, or *sensor_msgs* package provides the the messages for most common sensors.

1) Navigation: We used the following packages: *base_local_planner*, *gmapping* , *amcl* or *move_base*. The *Turtlebot_navigation* package provides the high level method for turtlebot navigation management but for more complex task the *navigation* stack (deprecated concept in recently ROS distributions) is required. With this stack we find the *base_local_planner*, that provides the implementation of the Trajectory Rollout and Dynamic Window for the robot navigation on a plane. The *gmapping* package presented as a ROS wrapper for OpenSlam's Gmapping supported in laser-based SLAM, in our case using the data from Kinect. The *amcl* package for providing the localization system and based in the adaptive Monte Carlo localization approach. The *move_base* package for offering an action system for robot movement.

2) Dialog: For the dialog system we are using our own package that wraps the gstreamer-pocketsphinx library and *sound_play* ROS package for voice generation. The text to speech component is supported on *Festival* software.

3) Manipulation: This task needs of *rosserial_python* package for Arduino control and message interchange. All the kinematics analysis for moving the arm are performed in our own package.

4) Perception: We are using different ROS packages for the perception task. First, we are using *openni_camera* package for the RGB-D sensors as Kinect or Xtion. For 2D sensors, as webcams, we are using *usb_cam* and *usb_cam* packages. We have to deploy both because hardware restrictions between the external webcam camera and the integrated one presented in the computer.

On top of this we are using the PCL library for object recognition and pose estimation using 3D cameras. Also we have our own packages for 2D recognition using the RGB webcam.

5) Planning and Execution: We have defined a high level component and a small database with the basic behaviors definition and world modeling. This was our first approach for the challenge set up but we are working in a middleware integration for simplifying the behavior development.

This component is presented as a finite state machine that activate and deactivate the necessary or unnecessary ROS components. The behaviors and some components variables are defined previously in a database.

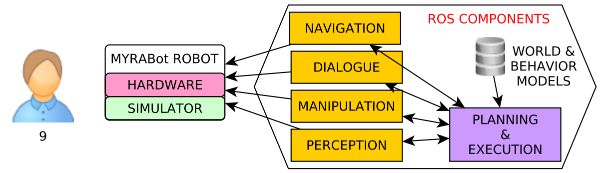

Fig. 6. Main software components in MYRABot

VI. Simulation

We have developed the MYRABot robot model for Gazebo. Gazebo is one of the most common environments for robot simulation. There are a lot of platforms available to test with it and also it has an easy integration with ROS.

We have also deployed the MYRABOT model in rviz, the 3D visualization tool for ROS.

The robot model for Gazebo is defined using URDF(Unified Robot Description Format). We defined the visual component with the physics characteristics by one side and the controllers in charge of the mobile unions are modeled by the other side. For educational reasons we have developed the simulation models in two phases, in the first phase we developed the arm, that we were using for simple kinematics research and in the second phase then we integrated this arm in the robot model for a full robot simulation.

A. Arm Model

The AX-12 servos have been modeled using the PR2 model whose main feature is the position and velocity control using a PID regulator. The arm model working autonomously can be seen in figure 7

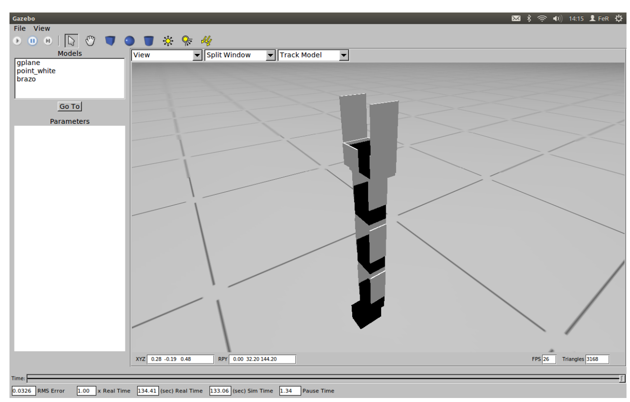

Fig. 7. Arm model in gazebo

B. MYRABot Model

The whole MYRABot model includes the base, the frame, and the robot sensors plus the arm model (figure 8).

We have used the iCreate model of Turtlebot in ROS. We also use the kinect model deployed in the Turtle Bot. The other sensors are modeled as an approximate physical representation and using the plugins available in the Gazebo environment.

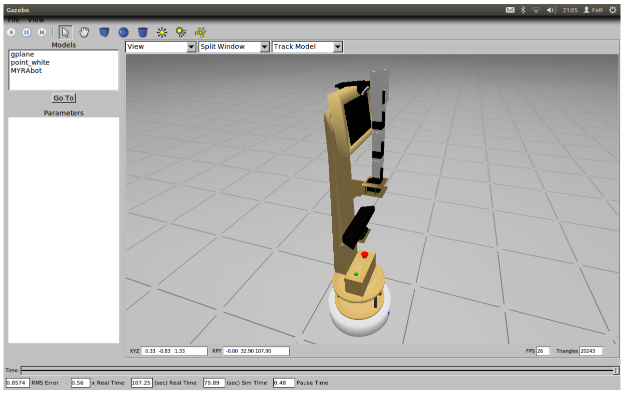

Fig. 8. MYRAbot model in gazebo

Fig. 9. a) REEM and MYRABot. b) Extra camera for object pose recognition

VII. RoCKIn Experience

The first RoCKIn camp 2014 took place in Rome in Feb 2014. The RoCKIn committee has defined for each year two phases. The first phase is focused in robot set-up and team collaboration. The second phase is focused in the challenge itself working against other teams.

We found pros and cons of the proposed techniques and software presented in the camp. The major advantage was that they offered a off-the-self solutions, so all teams were able to test it. The disadvantages were mainly: a) the proposed solutions only run in Hydro, a ROS distribution different of our Fuerte version; b) the second one was the high computational cost of the proposed solutions, in our case we have a netbook and this is a big problem; c) the last one was only related with the dialog solution, it needs a full Internet connection, without this, it doesn't work making it a big restriction in the @home arena .

Also, during the practical sessions we were able to identify some problems in our platform. From a software point of view, we found that ROS Fuerte distribution was too old for new software solutions. Our robot works but any other new feature has to be downgrading for Fuerte distribution.

We also find two problems related with the robot hardware. The first one was related with the robot sensors, we were not able to deploy some perception solutions for grasping because our 3D camera is situated in a lower position and it is used only for navigation tasks. In this way we decided to put an extra Xtion Camera on top of the robot as is shown in right picture of figure 9, it was possible thanks to the robot morphology.

The last problem was related with power supply, we burn our battery and were not able to feed kinect or arm without wires. The reason is that we carry our first prototype to the camp, and it was extensively used for labs experiments.

VIII. Conclusions

We have presented the evolution of a low cost robotic platform adapted for RoCKIn @home challenge.

The main contribution presented in this paper is the robotic platform for interaction built. It is at least 5 times cheaper than other similar robots as seen in table II.

The second contribution is that the platform design enable HRI tasks as manipulation and grasping, and interaction through the display. It is possible to adapt it in height. Also this frame design allows us to improve the platform with new sensors if we need it.

Component	Total	Description	Price (Euros)
Frame	2	Wood pieces	50
Computer	1	LG notebook	349
Arduino	1	Arduino Mega	50
Interface	1	DIY	50
Base	1	Roomba 520	299
RGB-D sensors	1/2	M Kinect/Xtion	150(x2)
webcam	1	Logitech	30
Button Box	1/(3)	Start, Power, Em.Stop	50
Arm	1	Bioloid	300
		Total	1528

TABLE II
Summary of components by price

Our conclusions related with the robot performance during the RoCKIn challenge are: a) we were able to migrate components to adapt our platform to competition rules, as others teams; b) we were able to integrate competitions components as MoveIt to our system (adapting it to our hardware restrictions) as is shown in figure 10; c) we have built a platform capable of making the same robotic task as the other robots but with an economically feasible platform, this make us think that this platform can be used as a first approach for other @home competitions as RoboCup.

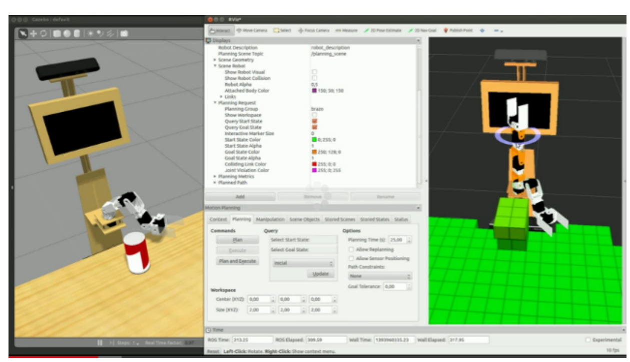

Fig. 10. MoveIt! for planning MYRABot arm

Finally we identified some hardware problems that are difficult to be detected in a research lab, as for instance, software integrations issues and power problems when all hardware components were running together, or the speakers situation that presents a handicap for the dialog. Also the performance of our netbook computer is a handicap when we are working with RGB-D sensors, but as we presented this does not prevent us to develop parallel solutions adapted to our platform able to fulfill the tasks

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