The Reem@IRI 2013 Robocup@Home Team Description

G. Alenyà[1] and R. Tellez[2]

[1] Institut de Robòtica i Informàtica Industrial, CSIC-UPC, Llorens i Artigas 4-6,
08028 Barcelona, Spain
[2] PAL Robotics, C/Pujades 77-79, 4° 4ª 08005 Barcelona, Spain
`http://robocup.pal-robotics.com/`

Abstract. This paper describes the Reem@IRI team for the participation at Robocup@Home 2013 competition. The team uses the robot REEM, a commercial service robot used mainly as information point in meetings, exhibitions and hotels.
In our research, special emphasis is devoted to safe navigation in human environments, and in perception and manipulation of rigid but mainly on deformable objects, like textiles. Therefore, open challenges tests and finals will show results of our investigation on that field.

1 Introduction

The Reem@IRI team consists of a team of professionals, researchers and students from three different partners: Pal Robotics, IRI and AESS.

PAL Robotics is a company based in Barcelona dedicated to the construction of Service Robots that work in dynamic human environments. Pal Robotics already participated at the 2006 and 2007 Robocup competition, at two different leagues, Large Humanoids size, and the Robocup@Home with robots REEM-A and early REEM-B, earning a winner place at the humanoids speed test of 2006, second place at the penalty kick test of 2006, and the same award at the 2007.

IRI (Institut de Robòtica i Informàtica Industrial) is a Joint Research Center of the Spanish Council for Scientific Research (CSIC) and the Technical University of Catalonia (UPC). Its presence in European research is strong, producing significant contributions in human oriented robotics. Research on the Perception and Manipulation Group focuses on enhancing the perception, learning, and planning capabilities of robots to achieve higher degrees of autonomy and user-friendliness during everyday manipulation tasks.

AESS is an association of students located at the Technical University of Catalonia composed by students of mechanics, electronics and computer science. Its main objective is to put in contact students with real robotics fostering the construction of small prototypes, participating in robot games, and organizing activities.

The robot used for this competition is the commercially available REEM robot. The purpose of using such robot for this competition is two sided: First, state-of-the-art algorithms for robots are tested on a complex robot on a stressing environment. Second, the robot learns new skills allowing him to stretch its field of application.

2 Focus of research/research interests

From the research point of view, two main interest drive our participation at the @Home league. First, we are interested in perception and manipulation of deformable objects in everyday scenarios. The problem is challenging considering its high dimensionality and the difficulties related to the uncertainty in the estimation of the state of the deformable, and the uncertainty of the outcome of actions performed on deformable objects. We have investigated what constitutes a good initial grasping point for a piece of cloth lying on a flat surface in an arbitrary configuration [1]. We have also proposed learning algorithms for the detection and grasping of particular parts on textiles [2]. Note that all these perceptions are intrinsically stochastic. Regarding object interaction, we are working on use these perceptions in a planning framework to manipulate textiles on a pile, for a.e. remove pieces one by one [3] with methods that consider explicitly the uncertainty in the actions of the robot [4].

We are interested also on the transference of these skills to the REEM robot, and we would like to formalize it. Perceptions are similar of those obtained in the lab with other robots, so the main difference resides in the precision of the manipulation pipeline. We are studying how the modeling of the different uncertainties in the outcome of actions can be formalized to objectively measure and compare performances, determining which kind of data support is needed to potentially allow the replication and comparison of the proposed experiments on a wider number of systems.

Second, it is very important for us to create a robot that can freely and safely move over all type of situations that can be encountered in a home environment. This includes different types of ground, many types of static and dynamic obstacles, and also other robots that may interfere the normal functioning of ours. REEM robot has already shown its navigation abilities in crowded dynamic environments, but many perception and obstacle avoidance problems when navigating in human environments still remain unsolved [5]. Specially challenging is the detection of all possible obstacles the robot may encounter, the classification of those obstacles as dynamic or static, and the detection of stuck/crash situations when sensors do not provide such information. We see the @Home environment as a test for the robot navigation skills under those unsolved situations.

We are handling re-usability explicitly in our development model. People from IRI develop most of the algorithms on their own robots: Segway mobile platforms and WAM manipulators. When possible we use common interfaces for the main robot systems (navigation pipeline, manipulation pipeline, perception pipeline..) and transfer becomes easier. We are identifying how to handle with the differences between all those robotics platforms and REEM robot, that

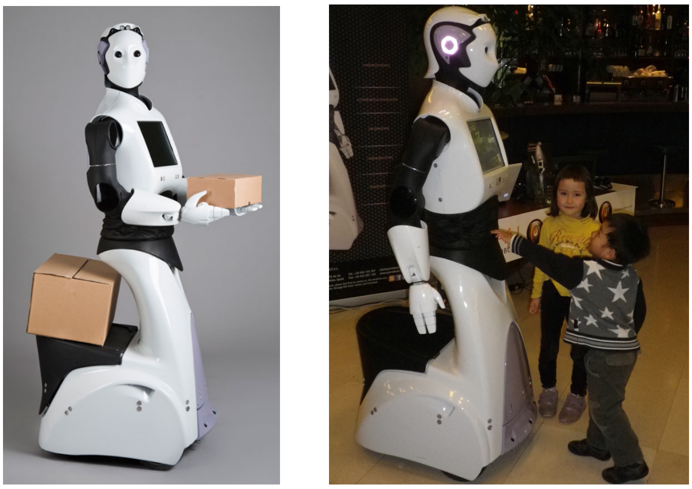


Fig. 1: Image of the REEM robot carrying 2 boxes, one with the arms and the other in the platform, and the robot with kids in a real shopping mall.

can be identified using calibration or more complex modelisation of actions and throughputs.

3 Robot platform

The robot used for this competition is REEM robot (Fig. 1), a robot built by Pal Robotics company that has already been demonstrated in real events. The purpose of this robot is to work as a Service Robot in real human environments, what makes the Robocup at home a perfect test bed for him.

Mechanically, REEM is composed of three different parts: a differential mobile base that runs on two motor wheels, a torso equipped with two 6 degrees-of-freedom arms with hands, and a head equipped with multiple sensors and with two degrees of freedom for pan and tilt motions.

The robot base is able to move the body of the robot inside a building, even over small obstacles of less than 2.0 cm like cables, notebooks, pens, etc. It is also able to move over ramps of less than 4 degrees of inclination. The base is also equipped with a laser sensor that scans the ground in order to avoid pitfalls. Additionally, the base has a special shape that allows the robot to carry stuff on its back up to 5 kg, like a suitcase, a box, etc.

The torso is composed of two arms with hands and two extra degrees of freedom at the hip that allow the robot pan and tilt the torso. This feature is specially required when trying to access difficultly located objects over a table, or to equilibrate the robot under certain conditions. It also provides more expressiveness to the movements of the robot. Hands have three degrees of freedom divided in three different fingers.

Table 1: Main characteristics of REEM robot

Weight	90 Kg
Height	1.70 meters
Battery autonomy	8 Hours
Degrees of freedom	22
Payload	30 Kg for the mobile base
	3 Kg each arm
Speed	4 Km/h
Computer	Core 2 Duo + ATOM

Fig. 2: Detail of the REEM head when equipped with the depth device.

The head contains several sensors that allow the robot perceive the world in the direction it is looking (cameras, microphone and sonars). It also contains a pair of round leds that show the power status of the robot. As a special feature for the Robocup competition, the head of the robot has been equipped with a depth sensor using a special structure that adapts the sensor to the head on a fashionable way.

REEM robot has several sensors in order to perceive the environment. The full list of sensors is the following:

Laser range finders : 1 sick laser and one Hokuyo laser for obstacle avoidance and SLAM.

Sonar ring : Located at the base of the robot, a ring of sonar sensors all around the robot are used combined with the laser for obstacle avoidance.

Stereo camera pair : Located at the head, two wide angle cameras are used to person detection and tracking, and object recognition.

Stereo microphone : Used to speech recognition and speech synthesis.

RGBD camera : Asus Xtion sensor that delivers registered color and depth. Located at the head of the robot (Fig 2) is used for object recognition. We use specifically depth information for the estimation of the deformable object state.

The robot has a touch screen that can be used to command orders to the robot or display information about the current situation, in order to help understand what the robot is doing (or tries to do). Additionally, the robot has three speakers, two in the front and one in the back, and they are used to broadcast sound from the touch screen, or the robot voice when speaking.

4 Software architecture

Software is divided in two different main layers: the *task planner* and the *complex actions*. The communication between these two layers is implemented using the Robot Operating System (ROS) framework [6]. When possible, we use standard ROS messages between them. This allows to easily compare and substitute state-of-art algorithms by our proposals, and vice-versa, and thus create a basis for comparison. For that reason it is important to use standard messages not only in its syntactics, but also in its semantics.

The *task planner* layer contains all the modules used to solve complex tasks. For the Robocup@Home competition this includes at least all the planners for the different tests. This modules are constructed to combine different skills. Planners are designed to take into account explicitly the uncertainty on perceptions and actions.

The *complex actions* layer contains subsystems that represent behaviours of the robot. Sometimes they can be complex and require the coordination of different robot skills, i.e. safe navigation, deformable object grasping, coordinated speech and motion, and sometimes they can be simpler. This layer is subdivided into 4 different domains: *skills*, *filtering/fusion*, *perception*, and *action*.

Perception and *action* domains treat interact with sensors and actuators respectively. Action modules are considered complete and they include all the configuration and knowledge about transformations between working and configuration space. Perception modules are less smart, and we have designed a *filtering/fusion* domain that contains some intelligence that permit operation on one unique sensor data, or allows the fusion and coordination of different sources of information. We have developed a fusion method that handles specifically the difference in refreshing rate of every data source [7].

Actions and perceptions, maybe before filtering/fusion, are combined into *skills*. These skills constitute the minimum unit that is used later for planning.

Robot navigation Due to the special characteristics in the sensoring of the robot base, a special algorithm for obstacle avoidance has been developed. The reason is that the robot is not round and its rotation center is not located on the physical center of the robot. The algorithm developed is based on Nearness Diagram one and divides the space in several security areas. This algorithm has been integrated into ROS navigation pipeline.

People detection and tracking We use different people detectors: with the images from the wide angle color cameras we use a face recognition algorithm based on FaceVacks libraries, and person detector based on appearance models [8]; using the horizontal laser on the base we have trained a leg detector that estimates pairs of legs. This different estimators are fused in a particle filter framework that keeps tracking of each person on the robot field of view.

Object recognition We have divided object recognition in two different scenarios. For far objects, a visual salience algorithm returns the probabilities of the different viewed zones Object recognition is performed using clusterization of features 3D object modelling is performed using an uncertainty reduction method to integrate different views of the same object [9].

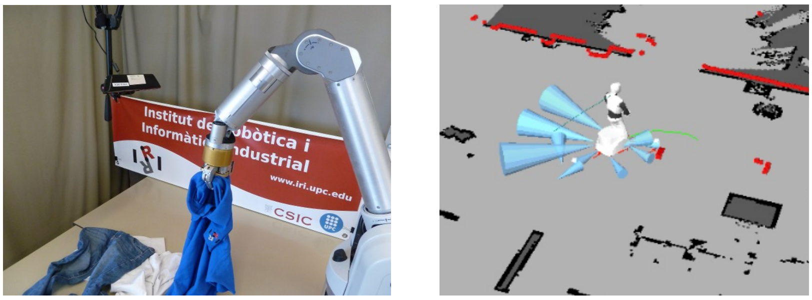
We have developed a measure of the "wrinkledness" in a point taking into account the depth information of its neighborhood. This measure is computed using a local de- scriptor based in the surface normals of a 3D point cloud. In particular, we use the in- clination and azimuth angles defined in the spherical coordinates representation of the normal vectors

In order to handle the large variability a deformed cloth may have, we build a Bag of Features based detector that combines appearance and 3D geometry features. An image is scanned using a sliding window with a linear classifier, and the candidate windows are refined using a non-linear SVM and a "grasp goodness" criterion to select the best grasping point [2].

Manipulation The object manipulation with robots has mainly relied on precise, expensive models and deterministic executions. Our goal is to explore if it is possible to achieve rather complex goals through a simple and inexpensive set of actions and perceptions. For low level control we use the manipulation pipeline of ROS to communicate with the OMPL trajectory planner and thus obtain a manipulator obstacle avoidance strategy that can be used in our different robotic platforms.

Given the great complexity of modelling deformable objects accurately, their manipulation remains an open research challenge. We propose a probabilistic approach to deformable object manipulation based on Partially Observed Markov Decision Processes (POMDP) where the action and perception deficiencies are compensated through interaction planning that efficiently leads to uncertainty reduction. Figure 3a shows an experiment execution where a t-shirts has been detected and a grasp has been planned and executed. We are also exploring Probabilistic Fast-Forward [10] for logic decision making.

Human robot interface Human robot interface (HRI) is based on the integration of state-of-the-art algorithms. Speech recognition is based on Sphinx free software and speech synthesis is based on the Loquendo TTS software. We have considered that HRI constitutes a unique action that integrates not only speech recognition/synthesis but also generation of gestures of the robot. Gestures provide expressiveness and clarifies what the robot is saying. It can also generate



(a) WAM arm used to develop manipulation algorithms and to test skill transfer

(b) Simulated environment with active sonars and laser values.

Fig. 3: Scenarios for software development: skill transfer and simulation.

a feeling of comfort in the person that is interacting with it. Robot gestures are generated by moving mainly hands and torso, and eventually, with facial expressions that can be performed a.e. using led lights to simulate a mouth, the eyebrows. Additionally, we are considering to use a virtual reality face displayed in the robot screen.

To control HRI we use message composed by (*speech*, *motion*, *expression*), that currently is used also in other of our robots.

Simulator Development of the robot skills is first done on the simulated robot. We use the Gazebo simulator integrated with ROS framework to test our development before testing on the real robot. [3] Furthermore, since our robot uses sonar range sensors for obstacle detection and those sensors are not simulated on current Gazebo version, we have modified the simulator to include such sensors. A patch has been sent to the Gazebo developpers to include such sensors in next versions of the simulator.

5 Real world applicability

The goal of the REEM robot is to be used in real environments helping people in their needs. REEM and some of its abilities have been applied to real world applications (for example, navigation, speech synthesis, people detection). However, by using only those abilities, at present, REEM robot can only be used as an information point because of its lack in object interaction, speech recognition, and people tracking. By adding these features required by many of the Robocup tests, REEM will be used in a wider number of tasks, allowing it to enter into other environments that remained closed for it, like for example, delivering at hospitals, performing house keeping tasks or acting in commercials.

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[3] A ROS package of our simulated robot is available at http://www.ros.org/wiki/pal-ros-pkg.

It can also be used as an standard platform for research experiments of any kind, either by programming its skills or by using the ones embedded.

The abilities developed for the Robocup2013 competition have been shown during the Ficomic fair, held on May 2012 in Barcelona.

6 Conclusions

The Reem@IRI team and the REEM robot have been presented. REEM robot has been used in real applications at hotels and meetings, and we are now developing new skills to better interact with humans in new scenarios.

In the development we use different robotics platforms in different conditions. Standardisation efforts in algorithms and their interfaces are performed to be able to transfer skills developed in laboratory conditions with different hardware to real scenario applications. We pursue to develop safe and secure robot motion in crowded environments. Regarding the perception and manipulation loop, we plan to show advances on understanding and manipulation of deformable objects, like textiles.

To our knowledge, this is the first time in the Robocup@Home league that a humanoid commercial Service Robot is used. This point shows the maturity of the field and also of the Robocup@Home league.

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