Humanoid Robotics and Human-centered Initiatives at IRI

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Abstract

The interest of the robotics community on humanoid robots is growing, specially in perception, scene understanding and manipulation in human-centered environments, as well as in human-robot interaction. Moreover, humanoid robotics is one of the main research areas promoted by the European research program. Here we present some projects and educational initiatives in this direction carried out at the Institut de Robòtica i Informàtica Industrial, CSIC-UPC.

Keywords: Humanoids, human-robot interaction, object modeling, manipulation, education.

1 INTRODUCTION

Nowadays the robotics community is paying increased attention to the field of humanoid robotics, and in Europe special emphasis is placed on the cognitive aspects of human-robot interaction in everyday settings. Humanoid robots are very complex, and require a huge effort in the integration of different hardware and software technologies. Some important advances have been accomplished recently, leading to the construction of several humanoid robot prototypes in laboratories around the world. However, humanoid robots and their capabilities are far from those expected by society.

Here we will present IRI's initiatives on this field, mainly concentrated in two areas: object modelling and manipulation (Sec. 2), and human-robot interaction (Sec. 3). Moreover, we present a successful educational initiative (Sec. 4), called "The Humanoid Lab", which uses small educational robots to introduce engineering students into robotics

2 PACO+

PACO-PLUS (www.paco-plus.org) is an IP project funded by the EU IST Cognitive Systems Program.

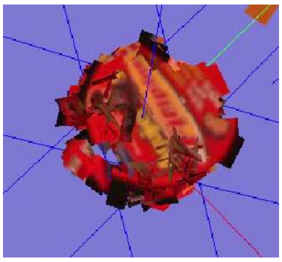
Figure 1: ARMAR-III humanoid robot, from Karlsruhe University, autonomously learning the rules to manipulate objects while avoiding collisions.

The objective of the PACO-PLUS project is to develop a new principle and methods to endow an artificial robotic system with the ability to *give meaning to objects through perception, manipulation, and interaction with people.*

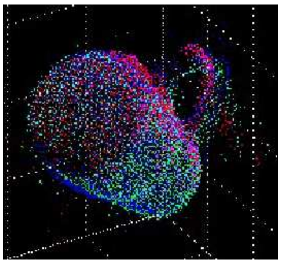
The leading idea behind PACO-PLUS is that Objects and Actions are inseparably intertwined [13] and that categories are therefore determined (and also limited) by the actions an agent can perform and by the world attributes it can perceive; the resulting, so-called Object-Action Complexes (OACs) are the entities on which cognition develops (action-centred cognition) [18].

Note that agents can in turn take the role of an object with active properties without violating the general framework developed. Thus each active agent becomes just another instance of an OAC. Through grounded perception-action loops, more abstract OACs are learned from existing ones by generalizing along axes given by motor capabilities, Gestalt statistics, guided and random exploration and goal-directed search.

Researchers from IRI lead the "Decision making,



(a) Model of a box, formed by small texture patches, obtained with a stereo camera



(b) Model of a mug obtained with a TOF camera

Figure 2: 3D object models generated autonomously

planning and evaluation" workpackage, while collaborating in other tasks within the project, such as "New categorization mechanisms in reinforcement learning" and "Neural network models for the computation of robot inverse kinematics" [9].

An important issue when the robot has to act in a domestic setting is to ease as much as possible the acquisition of new skills. Towards this end, haptic teleoperation and coaching strategies are being developed [14], as well as a rule-based learning system that asks for teacher advice when it faces an unexpected situation [2, 1]. The cause-effect probabilities underlying the workings of the system are refined through experience, and it is worth noting that rule relevance is achieved with few experiences, a key feature for the system to interact with humans. Integration on the ARMAR III robot [6] allows to learn and execute online, with the help of a teacher, complex tasks in a kitchen scenario (Fig. 1). The example application designed to demonstrate the system is to arrange cups on a counter avoiding collisions.

Another work within the workpackage lead by IRI is "Action selection for object modeling and exploration". The objective is to build the object models that will allow the system to perform complex actions on them, and thus create and refine OACs.

An object modelling algorithm has been developed that automatically selects the desired next view of the object and incrementally builds an object representation with the minimum number of views. It is based on entropy minimization criteria, and it can handle polyhedral and non-polyhedral shapes. Also, we have proposed a canonical representation of model uncertainties. The algorithm can handle object features extracted using stereo vision (Fig. 2(a)), and also depth points extracted with a TOF camera (Fig. 2(b)) [10]. We are now considering deformable objects, trying to detect and model non-rigid object shapes.

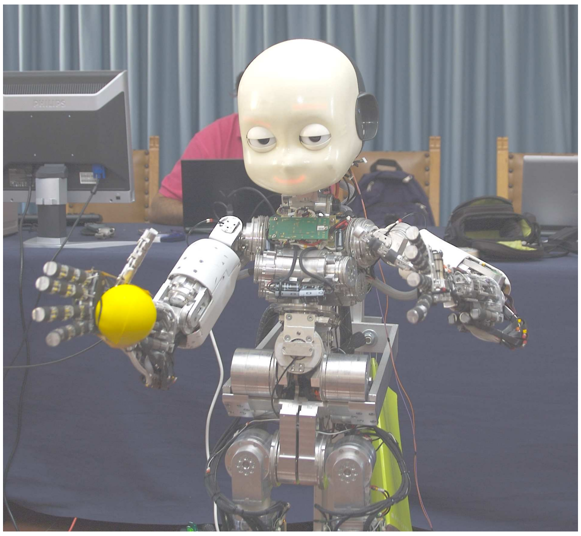


Figure 3: iCub robot to be used in cognitive related experiments.

Depth information from a stereo camera pair requires a precise calibration. As Armar-III eyes are active, and in particular their vergence, it is quite difficult to maintain their calibration. We have developed a new algorithm to recover the epipolar direction in the case of two uncalibrated affine views of an object [3]. In addition, we have developed a new algorithm to recover the depth of an object from the foveal-peripheral eye of ARMAR-III [5] and also its uncertainty [4], exploiting the fact that foveal-peripheral cameras are rigidly coupled and deliver 2 different zoomed images of the same object.

Also, in collaboration with the SPECS lab from Pompeu Fabra University, we are working with the iCub robot (Fig. 3) present in Barcelona. We are currently working on reaching and grasping primitives, and the final goal is to enhance the skills and abilities of the robot with new actions and learning capabilities.

3 URUS

URUS (http://urus.upc.es/) is a STREP project funded by the EU IST Cognitive Systems Program, and it shares some objectives with the the MIPRCV Consolider-Ingenio 2010 project.

The general objective of the URUS project is the design and development of a network of robots that in a cooperative way interact with humans and the environment for tasks of guidance, assistance, transportation of goods, and surveillance in urban areas. The focus of the project is in urban pedestrian areas, an important topic in Europe where there exists a growing interest in reducing the number of cars in the streets to improve the quality of life. Network robots can be an important instrument to address these issues in the cities.

The URUS project has been focused on several key issues: the development of a distributed architecture that allows sharing information and decisions among different types of robots (humanoids, mobile platforms, car-based robots), environment sensors (network cameras, Zigbee sensors, robot sensors, etc.) and humans (mobile phones, PDAs, etc.), through a common communication network [15]; the design and development of cooperative navigation and localization methods, which has lead for example to new robust localization methods [8] and new real-time software for mobile experimentation in cooperative environments [7]; the design and development of cooperative environment perception which has lead, for example, to new methods to track people using multiple cameras, new methods to overcome the problem of identification of people under cast shadows in open environments [17]; design and development of cooperative map building, which has lead to new methods for calibration and registration of 3D clouds [16] and new techniques for efficient vision-based loop closing for delayed-sate robot mapping [12].

We have also been working on the development of human-robot interaction techniques for assistance and guidance purposes. We have developed two robots, Tibi (female) and Dabo (male) (see Fig. 5), which have the capability to navigate, self-localize and interact with humans. These robots use three telemeter lasers for navigation and localization purposes, GPS and compass for localization, two cameras for navigation and one stereo camera for tracking and interaction with people. Moreover, they have a touch screen, microphone and speaker, also for interacting with people, and the head has illuminating LEDs which are used to demonstrate robot emotions.

For guidance purposes, we have developed a new shepherding technique for guiding people in urban areas [11]. This technique allows guiding several people using at least two robots, one at the head of the group which guides people, and the other one that tries to maintain people in a specific area while the group goes towards the goal. The robots detect when people go out of the area and look for them to return the missing people to the guided group.

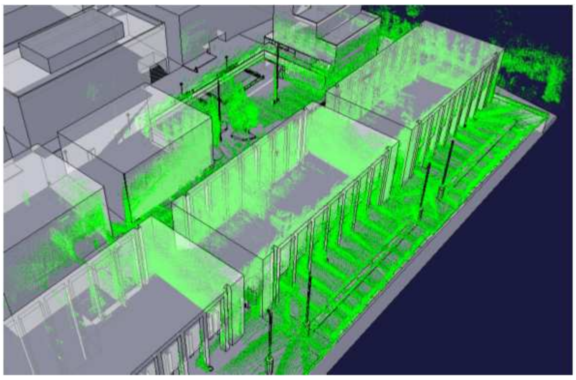


Figure 4: 3D model of the Barcelona Robot Lab, the new IRI facilities for ubiquitous and human-interaction experimentation.

Figure 5: Tibi, one of the two robots used in human interaction experiments.

4 THE HUMANOID LAB

The humanoid Lab project was started at the Institute two years ago. Its main goal is to approach robotics to students of both engineering and mathematics and to motivate them to continue working in robotics after their degree.

Not only stundt's learning of robotics topics is sought, but also the spreading of the knowledge gained to the international community who is working in the field of educational robotics. In this sense, all the mechanical improvements, electronic designs and software applications are shared freely through the web page of the project (http://apollo.upc.es/humanoide).

From the students point of view, the lab gives them an opportunity to collaborate in a multi-disciplinary group of people working in real problems, which allow them to complete their education. They have also the opportunity of developing their final degree projects within the lab. Finally, they also have the chance to meet other students with similar interests from other cities and countries.

The Humanoid Lab project uses simple humanoid robot platforms to introduce the students involved to the basic concepts of robotics, so that they see first hand the main problems in robot navigation, mapping, artificial perception and sensor fusion that currently exist and also the most used approaches to solve them.

4.1 LAB ORGANIZATION

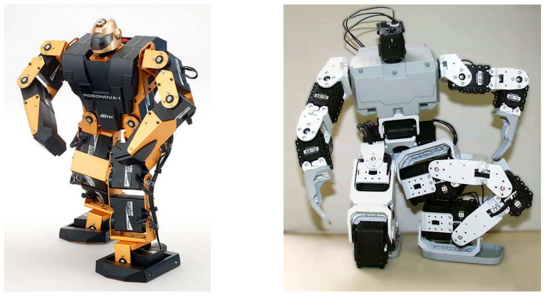
The project is coordinated by a Postdoc and several PhD students who guide the undergraduate students. Most of the students involved in the Humanoid Lab project are volunteers who spend some of their spare time working at the lab. Due to the limited amount of time they can dedicate, they are assigned small projects dealing with either mechanical, electronic or software issues, depending on the students interests and/or knowledge. There are also several final degree project students who are assigned more complex projects.

All these small to larger subprojects are aimed at equipping our robotic platforms with new sensors, new mechanical features and new control algorithms, as well as to develop new tools to help in the development. The main goal of these modifications is to provide the robot with the necessary behaviors and abilities to interact with the environment and perform several simple tasks.

Outreach is carried out in several different ways. Mainly by taking part in humanoid robot competitions, both at the national and international scenes: the CEABOT (http://www.robot.uji.es/documents/ceabot/) and the RoboCup (http://www.robocup.org/). There, lab's are compared against similar robots from other universities, giving also students the opportunity to exchange knowledge and learn new things.

Apart from the robot competitions, the Humanoid Lab project has also been present in several activities addressed to the general public such as fairs, school visits and open doors events, where some of the robots abilities are shown.

Up to now almost 20 undergrad students have participated in this initiative, including computer science, telecommunication and electronics engineers, mechanical engineers and mathematicians.



(a) Robonova. (b) Bioloid.

Figure 6: Standard humanoid robot platform used in the Humanoid Lab project.

A good measure of the success of the project is that several of these students that started as volunteers in the project, have ended up doing their final degree project at IRI, either inside the Humanoid Lab project or within other active projects of the Institute. Also, two free software grants from the Catalan government have been assigned to the Humanoid Lab to help developing the software framework.

After this initial success, the humanoid robot platforms have already been used in laboratory sessions of a robotics course at UPC, and in the near future a workshop is being planned.

4.2 ROBOT PLATFORMS

Two different humanoid robot platforms are being used in the Humanoid Lab project. The Robonova platform, shown in Fig. 6(a), which has 16 degrees of freedom, 5 in each leg and 3 in each arm, and a controller board capable of controlling these servos.

The second platform is the Bioloid platform, shown in Fig. 6(b), which is very similar to the Robonova platform, except that it has 18 degrees of freedom, 6 on each leg and 3 on each arm. Up to now, most of the work has been done on the Robonova platform.

The standard Robonova platform has some mechanical limitations, the most important being the lack of a 6th degree of freedom on the legs, which greatly increases the difficulty of turning around. Also with the sensors available for the robot, it is difficult to adequately perceive the environment and the state of the robot to perform even the most basic tasks. Finally, there exist also some problems with the original firmware which make it even more difficult to control the robot.

Most of the work carried out on the Humanoid Lab has been aimed at overcoming some of the problems and limitations of the standard platform.

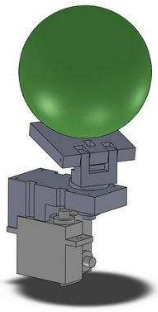


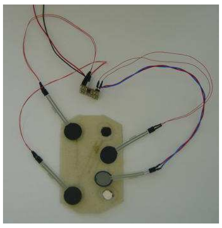
Figure 7: Pan & Tilt unit added to the head of the robot.

Figure 8: A prototype showing the 6th degree of freedom added to the Robonova platform.

Several mechanical features have been added to the robot. For instance, a pan & tilt unit has been placed in the robot's head (see Fig. 7) to add 2 more degrees of freedom, so that it can point the camera at any direction without actually moving the body.

Other mechanical modifications include a 6th degree of freedom on each leg that improves the overall motion of the robot. This modification is in the final development stage and initial experiments are encouraging (see Fig. 8 for the current prototype).

Two different kinds of sensors have been added to the original platform: sensors to perceive the environment and others to sense the current state of the robot. The first set includes ultrasonic and infrared ranging sensors to detect obstacles, pressure sensors on the feet, shown in Fig. 9(a), to detect holes or slopes on the ground and a web camera,



(a) Force Sensing Resistors (FSR) used to sense the pressure of the feet against the ground

(b) Camera placed on the pan & tilt unit used to perceive the surrounding environment.

Figure 9: Some of the sensors used to perceive the environment around the robot.

shown in Fig. 9(b), to add scene understanding capabilities.

Sensors that estimate the current state of the robot include tilt and acceleration sensors to estimate the motion of the upper body, that detect when the robot is falling or getting unstable. Together with the sensors, the needed acquisition electronics and control software have been designed and developed.

Control algorithms have been improved with the addition of the sensors, which allowed to close the control loop. Also, both direct and inverse kinematics of both the arms and legs of the robot have been derived, making it possible to improve the motion of the robot. With all these modifications, the overall controllability of the robot has improved, but the computational requirements have also increased.

In order to fulfill the data processing requirements, a small embedded computer running Linux has been added which is responsible of acquiring the data from all the sensors, including the web camera, and of controlling the robot, thus closing the control loop (see Fig. 10). This processing unit also allows the robots to communicate via a wireless connection with other robots or a host computer to exchange data.

4.3 CURRENT WORK

Currently there are 8 students working in the lab. 3 of them are doing their final degree project on the following subjects:

- Development and integration of the sensor acquisition software into the software application developed in the lab.
- Development of a humanoid robot simulator capable of handling the robot motion, the sensory feedback and the environment.

(a) Backpack to protect the embedded PC on the robot.

(b) Detail of the interior of the backpack with the embedded PC and the battery hole.

Figure 10: Backpack designed to carry the embedded PC and its dedicated battery.

- Development of a communication framework between the robots and a host computer to exchange information.

The remaining stundents are working on smaller projects concerning the following subjects:

- Development of basic algorithms with the standard Robonova platform to test the advantages and drawbacks of the modified platform.
- Development of a new firmware for the servo controller to eliminate some of the problems and to add new features like the serial control of the servos.
- Development of new mechanical features like the 6th degree of freedom for the legs and an improved version of the pan & tilt.

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