Towards real-world applications of humanoid robotics: the Robot-An Lab case

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Abstract— **Robot-An is a research site where Japanese and Italian robotics scientists cooperate on common humanoid robotics issues. Currently three main robots are being developed: the iCub, the ARTS Humanoid and the SABIAN (SAnt'Anna Biped humanoid). The research issues are not limited to hardware development but also to low-level control architecture design and to the implementation of cognition and environment interaction skills.**

I. Introduction

The Robot-An Lab is a joint laboratory between the ARTS (Advanced Robotics and Technology Systems) Lab of Scuola Superiore Sant'Anna (SSSA of Pisa, Italy) and the Takanishi Lab of Waseda University (Tokyo, Pisa). It was established in 2007 in Pontedera and organized similarly to ROBOCASA, the first SSSA-Waseda joint lab (Tokyo, since 2003). Currently the Robot-An members are 10 (2 post-doctoral fellows, 3 PhD candidates and 5 MSc students) and work on three main robots: the iCub, the ARTS Humanoid and the SABIAN (SAnt'Anna Biped humanoid). The scientific background is wide, from computer science to mechanical engineering. Even if only the SABIAN started off from this Italian-Japanese collaboration, all the research activities that concern humanoid robotics were moved from the ARTS Lab to Robot-An with the aim of improving the exchange of competences among SSSA researchers in a very interdisciplinary way.

II. Research Issues

The Robot-An issues are various and complementary; however they can mainly distinguished into two main groups: short and medium/long term issues.

Short-term issues could be identified in the design of specific hardware or in the implementation of robotic tasks. On the other hand, the implementation of a robotic skill is not a simple fusion of a set of robotic skills but opens a large set of parallel and complementary robotic issues that cannot be handled at the current state of robotics science.

However, even if hardware development is mainly identified as a short-time activity, it has to pointed out that the design criteria must be based also on a long-term research strategy. Any robotic platform has to be modular (i.e. in order to cope updates given by software improvements) as the hardware developer has to see beyond current engineering challenges. Taking in account the models (i.e. from neurosciences) adopted in a long-term scenario and estimate possible future requirements is thus mandatory.

A list of the main short-term issues in Robot-An could be the following:

- Humanoid and sensor design
- Implementation of vision modules for object tracking, smooth pursuit and adaptable grasping
- Biped locomotion (in a known environment)

On the other hand, in a medium/long term research view the issues are:

- Biped locomotion in an unknown environment
- Object affordance (recognition, tracking, grasping and fetching) and Fine Manipulation
- Humanoid Total Control

In the following section the three main robotic research platforms are presented in detail.

III. Current Projects

A. The iCub

The RobotCub project is a research initiative dedicated to the realization of embodied cognitive systems. It has the twin goals of creating an open humanoid robotic platform for research in embodied cognition and exploiting this platform in the study of the development of cognitive capabilities in humanoid robots. This cognitive system (the iCub) will be shaped, physically and mentally, like a 3 years old child. The iCub will be able to learn how to interact with environment through manipulation and gesture, in a bi-directional way (production/interpretation), and how to develop its perceptual, motor and communication skills to perform goal directed and manipulation tasks.

Manipulation plays a key role in the development of cognitive capability. Consequently, the design was aimed at maximizing the number of degrees of freedom of the upper part of the body. The total height around 90 cm and the total number of DoF is 55. The sensory system includes binocular vision and haptic, cutaneous, aural, and vestibular sensors. The first iCub was officially shown in October 2007.

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The SSSA iCub is currently a partial subsystem composed by the torso, the right shoulder, arm and hand; by the end of 2008 it will be provided also with the head. Functionally, this system will be able to coordinate the movement of the eyes and hands, grasp and manipulate lightweight objects of reasonable size and appearance. This will allow the system to explore and interact with the environment [1].

Thus the main research issues are mainly two: 1) the integrated design of mechatronics and (proprioceptive and exteroceptive) sensors together with the low-level control of the correspondent robotic subsystem (i.e. the hand); 2) The software development of vision (i.e object tracking) and grasping skills (i.e. object affordance and manipulation).

B. *The ARTS Humanoid*

The ARTS Humanoid is a robot with an arm-hand-head system aimed to perform adaptable grasping. Adaptability is intended with respect to object shape, size, weight, material and location, as well as to robot sensory and motor configuration. Though this general problem has been studied widely in robotics, both adaptable grasping and grasping flexible and soft objects are still challenging problems, especially if investigated outside of manufacturing contexts and with humanoid robotic systems.

In a perspective view, the proposed functionality of adaptable grasping and of manipulating fabrics will be a basic capability for a humanoid robot intended to be a partner and assistant at home. The proposed task requires a high performance sensory system, in terms of richness of the visual and especially tactile sensory information, of perceptual processing of large amounts of data. It also requires to the robot quite advanced dexterous manipulation capabilities of both the arm and the hand; furthermore the implementation of the sensory-motor coordination required will be derived from neuroscience models [2].

Within the project a new five-fingered hand was fabricated with a rich sensory system. Regarding the control system for the grasping, different procedures are investigated, as vision-guided reaching and touch-based grasping. Learning is being implemented in order to allow the system to generate appropriate internal models to guide grasping. The training of the system will be both off-line, i.e. preliminary learning phase, and on-line, i.e. the system will learn more grasping strategies when proposed different objects.

The system will perform reaching and grasping in two steps:

1. Pre-shaping: the system moves and orients the hand in a proper pre-grasping position, based on the visual input, and generates an expected sensory configuration;

2. Grasping: the system grasps the object and adjusts the fingers in order to reach the Target Expected Perception (TEP). TEP is a sensory image composed of the analogue data provided by the sensors of the hand.

C. *The SABIAN and its Future Developments*

The SABIAN project started in 2006 with the technology transfer of the design and of the control architecture of the WABIAN (WAseda BIped humANoid) 2. The development (both hardware and software) of this humanoid has been articulated in two phases; the first one is related to the development of a copy of the legs, waist and torso of the original robot. This configuration (LL) is the minimum configuration for generate walking patterns and make the robot walk. The control system is the Japanese version [3].

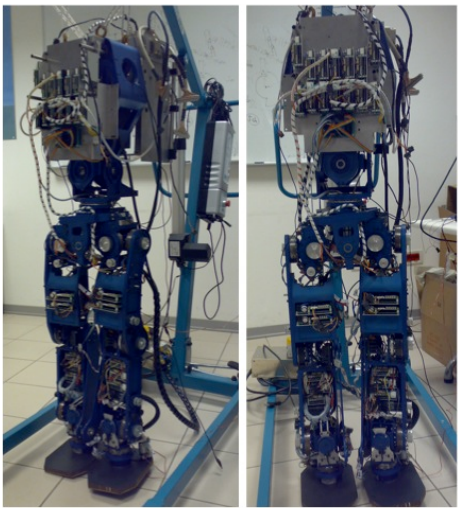

Fig. 1. The SABIAN LL

The second phase is original and is aimed to merge in the SABIAN all the competences developed in the Robot-An. Currently a new policy that produces a control law for a biped walking robot is in the simulation phase; this policy is the result of a process in which the robot learns to walk using reinforcement learning techniques. It will be tried soon on the SABIAN LL (see fig.1). New 7 DoF arms and 8 DoF hands have been designed for providing the robot with reaching and grasping capabilities. Each hand performs grasping (max weight 1 Kg). A head based on the iCub version (4 DoF neck) will enable the SABIAN to perform the same task of the ARTS humanoid; furthermore bimanual cooperation will be possible and vision will be exploited for navigation and avoiding obstacles during walking.

Obviously the level of complexity will raise several critical issues as balancing the robot while carrying objects and exploring the environment. To this purpose several dynamic simulation are ongoing work. Moreover the high-level control system will have to manage an extremely high number of processes in real-time; the "total control" of this full bodied biped humanoid is without any doubt one the main long-term research issue in progress.

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