The RobotCub Project: Research on the iCub Platform

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Abstract—This text is an introduction to the humanoid robotic platform iCub and the RobotCub project. The importance of an embodied humanoid robot for the study of human-like cognition is briefly explained and the idea of a completely open-source platform is introduced. The RobotCub is a project financed by the European union commission, with the objective of advancing the current understanding of cognitive systems. The platform is essentially composed of a physical humanoid robot named iCub and a physically realistic simulator. Some comments on the works from the literature, related to the project, are made and future work is proposed.

Index Terms—Embodiment, humanoid robotics, simulated robotics, cognition, artificial intelligence, iCub, RobotCub.

1 Introduction

ONE of the turning points in the history of artificial intelligence was the publication of two papers by Robert Brooks named *Intelligence without reason* [1] and *Intelligence without representation* [2].

Until then it was believed that any system exhibiting a certain degree of perceived intelligence must operate by manipulation of symbols [3], as stated by Newell and Simon [4]: "a physical symbol system has the necessary and sufficient means for general intelligent action".

Brooks argued however that to build an intelligent system one could not rely on symbolic representations, but have its representations grounded in the physical world, since the world is the best model of itself there could possibly exist [5]. In order for this to hold true, the system or robotic agent must have a body, and this body must be situated, or embedded, into an environment. This intelligent agent must be embodied.

Embodiment can be understood as an agent possessing a physically-active body capable of moving in space, manipulating its environment, altering its state and experiencing the physical forces implied inherent to this interaction [6]. Ziemke however characterized five different types of embodiment [7]:

1) Structural coupling between agent and environment: meaning the system can be disturbed by the environment and the environment can be disturbed and influenced by the system as well.
2) Historical embodiment: which is formed by the resultant history of the previously mentioned structural coupling
3) Physical embodiment: the agent is capable of acting on the environment by the exertion of forces
4) Organismoid embodiment: In the sense of a morphological or functional similarity between the robotic agent and other organisms, such as humanoid robots, insect-like robots and so on and so forth.
5) Organismic embodiment of autopoietic, living systems: case when the artificial agent is closer to a biological one.

The first type of embodiment is more general than the following ones and Ziemke suggests that humanoid embodiment could be considered a special case of organismoid embodiment [7]. He then stresses the potential interest of this sort of system for cognitive science.

The fundamental idea is that the morphology

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of the robot is a crucial part of its cognitive system. Based on this argument many humanoid robotic platforms have been developed and used for research in various fields such as psychology, computer vision, control and social interaction.

This paper reports about the iCub humanoid robotic platform, produced by the RobotCub research initiative which aims at broadening our knowledge on cognitive systems such as these.

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2 The RobotCub project

RobotCub is the name of an European research initiative with the objective of studying embodied cognition. Its goal is then to create a humanoid robotic platform, called iCub, in order to advance the current understanding of cognitive systems.

Since it is assumed that manipulation plays a vital role on the development of cognitive capability, special attention was given to the development of iCub's upper part, including arms, torso, head and hands [8], giving it a maximum number of degrees of freedom.

The robot was build to have the overall dimensions of a 3.5 years old child. It has a total of 53 actuated degrees of freedom being 41 for the upper body and 12 for the lower body.

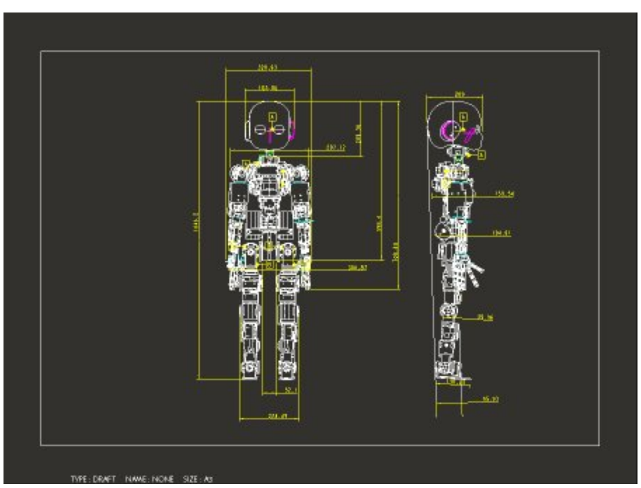

Fig. 1. iCub CAD drawings: front and side views

Special attention was given to the construction of iCub's hand, which can be seen in Figure 2. The flexing of the fingers is controlled by those tendons while their extension is dictated by spring system. The thumb, index and middle finger have independent actuator while the last two fingers are actuated together by the same motor.

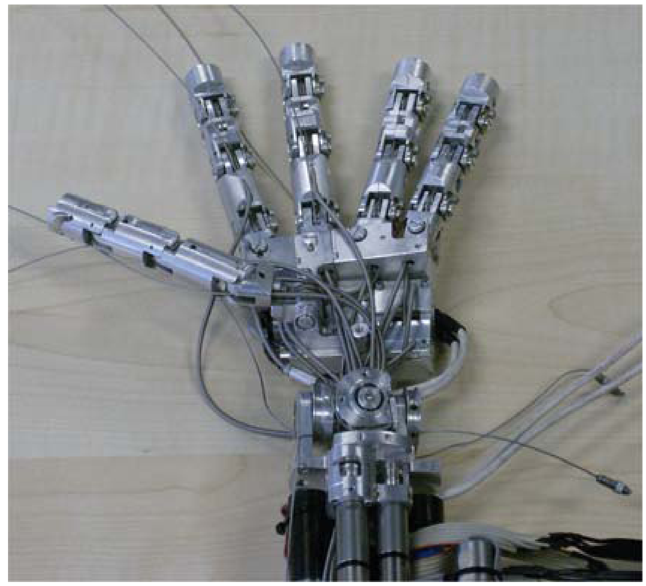

Fig. 2. iCub hand: 9 degrees of freedom, actuated by tendons moved by motors located in the forearms [9]

The robot's lower body is able to support crawling, as can be seen on Figure 3, giving iCub the ability to explore the surrounding environment and revert to a sitting position so it can manipulate objects on the floor.

The constraints in size, available technology and the experience of the consortium were the deciding factors while making design choices. The robot includes electric motors do control its joints, cameras, microphones, gyroscopes, linear accelerometers, encoders, temperature and current consumption sensors, force/torque sensors and also tactile sensors [8].

The software controlling iCub is potentially parallel and distributed, being based on a middleware called YARP.

2.1 YARP

YARP stands for "Yet Another Robot Platform", and is an open-source platform for

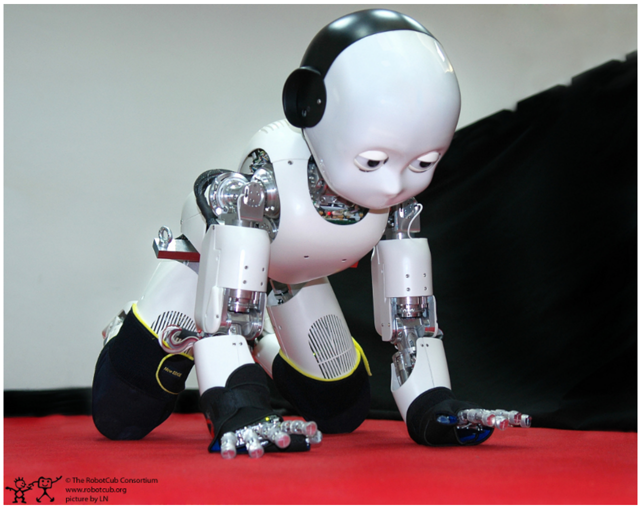

Fig. 3. iCub robot crawling on the floor

long-term software development for applications that are computation-intensive and depend on constantly changing hardware.

One of the major problems concerning humanoid robotic platforms until now has been the fact that most of the technology developed for a certain robot couldn't be properly reused in another project. All controlling software and behaviour modules developed end up being discarded once the project reaches its final stage.

YARP was developed to remedy this ongoing situation in humanoid robotic research, its main objective being to allow collaboration between working groups. It is essentially modular, which facilitates adapting to ever changing hardware, and SO independent [10]. Most of its programing is done in C and C++, but there are bindings for Java, Matlab, C#, Python and Perl as well.

2.2 The iCub Simulator

As previously explained, an iCub robotic unit, even being open-source in nature, is not easy to construct and not cheap to acquire. Being an expensive tool of research, it is only natural trying to find alternative ways to perform some of the tasks meant to be run on iCub. Simulating the robot with realistic physical interactions bring about a number of advantages to the researcher [11]:

1) Allows studying the embodied agent without the need to building it in advance.
2) The simulator can be used as a platform to quickly test new algorithms and check for major problems in its implementation.
3) Getting familiar with the platform and with how to perform experiments latter to be tested on the physical platform.

The iCub simulation can be see in Figure 4, where the robot is seen behind a table with a few objects on it [11].

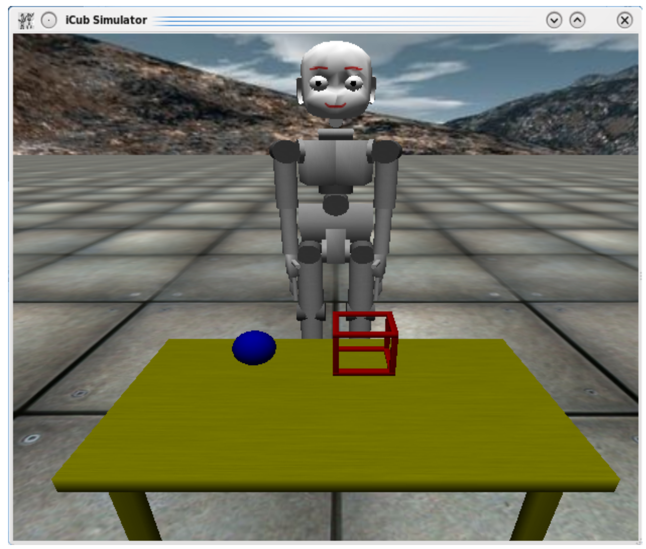

Fig. 4. iCub simulation with surrounding objects

The simulated robot was built trying to achieve an exact replication of the physical robot, and the environment has its parameters, such as gravity and friction, similar to real environment conditions.

Special care was given to the process of choosing the software tool to compose the final simulator. Since one of the main objectives was to keep it open-source and easily available to any researcher looking forward to perform experiments on it, the simulation was composed by the following free platforms:

1) ODE Physics Engine
2) OpenGL Rendering Engine
3) YARP protocol

ODE stands for "Open Dynamics Engine" [12] and it is used for simulating the rigid bodies forming the robot and for the collision detection algorithms as well. Since the processing power required to perform the full simulation is quite big, the rendering of the whole scenes was performed in OpenGL, producing a smoother simulation. And at last, YARP, the same protocol used on the physical robot, was chosen as an interface software between iCub's hardware parts. Commands are sent to the robot as YARP instructions and feedback from iCub simulation's sensors are acquired from the model the same way [11].

3 Working With iCub

The RobotCub, being a recent project as it is, already has a number of articles related to it in one way or another. Basically, there are three types of works that can be found in the literature at the moment: work related to RobotCub project, work on the development of iCub and its simulator and work using the developed platform.

In the following sections, the nature of these projects will be briefly commented and some examples of each will be given.

3.1 Works related to the RobotCub project

These are the works that have a direct or indirect relation to the RobotCub project. The *6th* framework (FP6) of the European Commission supported a number of works on the topic of Cognitive Systems in a broad way.

An example of such a work is a *Survey of Artificial Cognitive Systems*, as can be seen in [13]. In this survey an overview of cognitive architectures and development of mental capabilities in computational agents is presented.

It compares the cognitive and the emergent paradigms of cognition. For a cognitive system, cognition is representational, based on the manipulation of symbolic representations of the state and behaviour of the external world. For the emergent approach on the other hand, cognition is mainly a self-organization processes which enables the system to become viable and effective in its environment.

The paper then describes some cognitive architectures that work with both concepts. Like the cognitive architecture SOAR, that works in a cognitive way, the Global Workspace concept, that is emergent in nature, and Cerebus, an example of a hybrid architecture.

After describing and comparing these and a number of other architectures, the authors conclude the paper pointing some of the most important factors in the development of cognitive systems, such as the importance of embodiment and a history of interactions [13]. Much like the Physical and Historical embodiment previously stated by Ziemke in [7] respectively.

3.2 Works on the development of the iCub platform

Perhaps the best article to learn more about the iCub platform is the official paper [9]. This article has been rewritten and updated as the project developed, and reports the RobotCub project and development of the iCub humanoid robot. Most of its content has already been described in Section 2.

Another example of work on the development of the iCub can be seen in [14]. The paper describes the development of an anthropomorphic hand for the iCub. As previously explained, manipulation plays an important role in the development of a cognitive system. And that is the reason why so many degrees of freedom were dedicated to the upper part of the robot and, in particular, to its hands. The paper describes how the selection of the degrees of freedom was done so optimal grasping and manipulation could be performed. It is an "ongoing work" report, much like many of the articles on the development of the iCub robot prior to 2007.

3.3 Works using the iCub platform

The most recent works related to the RobotCub project are those using the iCub as a platform for testing and evaluating new algorithms and robotic interactions.

These works are the most interesting ones to those who would like to investigate embodied cognition and all its related subjects such as cognitive architectures, behaviour and action selection, humanoid control systems, embedded computational vision and so on and so forth.

An example of a highly important behaviour a humanoid robot must be capable of performing is the grasping behaviour. In [15] for instance, the authors describe a technique for preparing the robot to perform a grasping behaviour. The objective is to estimate the 3D position of both the object to be held and the robot's hand in space.

The processes consists of two phases:

1) Positioning the hand near the object in a proper configuration
2) Applying a precise hand-to-target positioning of the hand

Both the hand and the object are approximated as ellipsoids and the idea is that more precise movements are learned by experience.

The first phase comprises of wide movements based on the knowledge of where the object is and of the robot's arm dynamics/kinematics. As soon as the hand gets near the object to be held, and both are in the visual field of the stereo cameras, the second phase starts. The second phase makes use of the CAMSHIFT [1] algorithm, a method based on colour histograms. Due to the method's dependence on colour, it is assumed that the objects have sufficiently distinct colours for the algorithm to work.

The results show that the method was able to identify the two objects in question, hand and object to be grasped, as correctly oriented ellipsoids. Further work was proposed on improving pose estimation and implementing it in actual servoing and grasping experiments.

4 Conclusion and future work

Most of the work destined to be implemented in the physical iCub can be initially developed on its simulated version. Being a physically realistic simulation of the real robot and its surrounding environment, it can be used to implement vision algorithms, such as the example given in Section 3.3, locomotion control as in [16] or [17] and many other behaviours related to humanoid robotics.

Being a completely open-source platform, both hardware and software alike, the iCub presents itself as a unique opportunity to further our knowledge on humanoid robotics and on human level cognition in a broader sense. With a growing community of researchers, and thanks to its modular architecture, it will become easier to develop on the platform and also to cooperate with other researches and laboratories.

Future work should encompass the continuity of reviewing recent works on the platform, learn more about its structure and implement some fundamental behaviours, such as grasping or following objects. In a following moment, a general control system for those behaviours shall be implemented, such as behaviour networks or cognitive architectures. The intention would be not only to control the robot in a more holistic manner, but also to investigate some particular characteristics of the chosen control system and its implications.

1. please check reference [15] for further information on how they have applied it

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