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Project acronym: iCub Body Schema
Project title: Body schema learning and adaptation in the iCub humanoid robot using whole-body tactile information
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Scientist in charge: Prof. Giorgio Metta, Host: Fondazione Istituto Italiano di Tecnologia

PUBLISHABLE SUMMARY

The goal of this research endeavor has been to model the mechanisms of biological body representations in the iCub robot and, thereby, simultaneously develop new technology. We started from looking at human studies and abstracting general principles that were then transformed into an implementation on a humanoid robot. This served two important goals: i) to concretely articulate and test hypotheses from empirical sciences, and ii) to develop robots with unprecedented autonomy and resilience. This project was intrinsically multidisciplinary: It encompassed psychology and the neurosciences from the cognitive sciences and robotics from the engineering sciences and, united by the notion of body representations and their autonomous learning.

The flexibility of humans can be, at least partly, attributed to the way the brain represents and updates the properties and current state of the body. However, the mechanisms of the so-called body schema are still not understood. Therefore, modeling and implementing body representations can serve to crystallize known biological facts and simultaneously design robot controllers which can perform with the reliability and adaptability of humans. The iCub robot with a human-like morphology and a corresponding set of sensory and motor modalities is a perfect tool for this task.

State-of-the-art robotic technologies rely on preprogrammed models and largely lack the capacity to adapt to unexpected changes to their bodies or the environment. In order to expand the domain where they can be applied, they need to respond more autonomously, flexibly and robustly. This project has employed the iCub humanoid robot, recently equipped with whole-body tactile sensing, to address these challenges by developing new methods to (i) automatically acquire and adapt models of the complete robot’s body; (ii) move in unknown cluttered environments using whole-body awareness, thus preserving the robot and other people’s safety.

Achievements
The contribution of this work toward cognitive sciences consists in a set of models on a humanoid robot that address the mechanisms behind learning, adaptation, and operation of multimodal body representations. Through concrete implementations, progress has been made in clearing up the muddy waters of the concepts and notions invented to describe body representation. In particular, individual case studies have addressed the development of tactile and proprioceptive as well as peripersonal space representations. Furthermore, we have worked with empirical scientists directly, in a bi-directional, cross-fertilizing loop – in particular with developmental psychologists Jeffrey J. Lockman (Tulane University, New Orleans, USA), J. Kevin O'Regan and Jacqueline Fagard (CNRS, Paris Descartes, France) studying early infant body knowledge. This work tied in with computational models that studied how body exploration and self-touch experience facilitates learning body models (see Fig. 1).

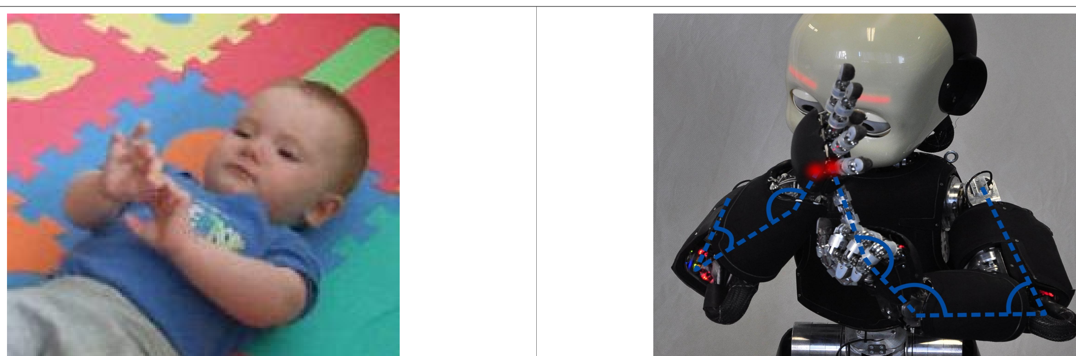

Fig. 1. Self-touching behavior in infants (left) and the iCub robot (right). The correlations in tactile, proprioceptive, visual, and motor information may bootstrap learning of own body model.

At the same time, the project aimed at designing novel robot controllers which can perform with the reliability and adaptability of humans. Tactile sensing over the whole body allows the robot to (i) automatically acquire models of its body through self-touching behaviors and (ii) move in unknown cluttered environments using whole-body "awareness", preserving the robot's and other people's safety. Toward the latter goal, a number of case studies in the context of this project studied autonomous learning of peripersonal space representations / safety margin around the robot's body. These were then complemented by work on controllers providing whole-body avoidance triggered by visual or tactile targets. Most recent work deals with real-time whole-body planning and combination of reaching tasks while preserving the safety margin (see Fig. 2).

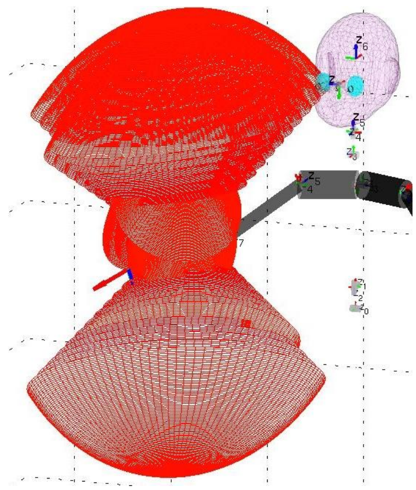

Fig. 2. (Left) Learned peripersonal space / safety margin around the robot's right forearm. (Right) Exploiting the safety margin for safe physical human-robot interaction.

Impact

The European Research Area (ERA) hosts excellent, highly competitive, research in artificial cognitive systems. The host institution – IIT in Genoa – plays a key role in this area thanks to the development of the iCub humanoid robot. The iCub is a mature research platform and has become a de-facto standard in cognitive and developmental robotics. This gives ERA a critical competitive advantage, since it allows gathering a critical mass of researchers to disruptively push the state of the art in artificial cognitive systems.

This project specifically ties in with recent computational modeling works in neuroscience that are starting to embrace more realistic settings. In the long term, better understanding of the mechanisms of body representations could help in the treatment of patients suffering from related neurological disorders or amputees. At the same time, the technology developed in this project (automatic self-calibration and reaching with whole-body awareness) is likely to impact on practical applications with fallout into new automation markets and a reduction of cost due to programming and reprogramming of robots. Furthermore, the technology is highly relevant for service robotics. Anywhere a service robot can be of use, we are likely to find a space that is shared with other people and whose level of clutter is beyond the capabilities of the robotic systems of today. In short, the expected results will tackle fundamental problems that can make the transition from traditional industrial robots to robots that work alongside human workers or in our homes.

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