IEEE International Conference on
Robotics and Automation

iCub and friends

A workshop on Open Source robotics to celebrate the iCub 10th birthday

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http://www.icub.org/other/icra2014-workshop.html

The iCub is a humanoid robot shaped as a four years old child. It is available as an open system platform following the GPL license. The iCub was originally designed by a consortium of 11 partners guided by the Italian Institute of Technology, with background ranging from engineering to neurophysiology and developmental psychology, within the RobotCub Integrated Project funded by European Commission through its Cognitive Systems and Robotics Unit. The iCub can crawl on all fours and sit up. Its hands allow dexterous manipulation and its head and eyes are fully articulated. It has visual, vestibular, auditory, and tactile sensory capabilities. In the past few years the community of researchers working on the iCub grew at a constant pace. Today there are more than 25 iCub platforms available worldwide. Simultaneously the platform evolved significantly in terms of its sensors and actuators. Thanks to the recent improvements the iCub is now equipped with: whole-body distributed tactile and force/torque sensing, series elastic actuators for compliant walking experiments (the COMAN actuators) and movable head with microphones, speaker, actuated eyes, eyelids and lips for speech and human-robot interaction studies. The key advantage of the iCub is that it is an integrated platform that allows the study of complex tasks that require speech and auditory perception, vision as well as proper coordination and integration of sensory data and control. We believe that this, more than ever, requires that researchers with different expertise join forces and start working together. Having platforms with compatible software and hardware is clearly a unique opportunity for collaboration. This workshop is the third in a series happening approximately every two years and, in particular, it will present a cohesive description of the iCub-related activities ranging from software development, control, vision, cognition and hardware, sensors and so forth.

Objectives

This workshop has two goals. The first goal is to bring together researchers working on the iCub humanoid robots and to present a complete overview of their recent activities. In particular we welcome contributions that demonstrate complex tasks that involve integration and coordination of several sensory modalities and whole-body control. The second goal is to foster collaboration among researchers that are working on different disciplines to advance the state of the art in humanoid robotics. In addition, the workshop will serve as a venue to start the preparation of a special issue for a prestigious journal. To conclude, with this 10th birthday workshop we aim at:

- Demonstrating the current development of the iCub platform;
- Providing an overview of the research on the iCub platform;

- Giving the opportunity of demonstrating and discussing recent results of integration activities;
- Advancing the state of the art in humanoid robotics by fostering collaboration among researchers working on different areas of robotics as e.g. speech, machine learning, vision, manipulation, locomotion, and whole-body control.

Topics of interest

- Speech and auditory perception
- Human-robot interaction
- Vision
- Machine learning
- Locomotion and whole-body control
- Manipulation
- Software engineering for system integration

Acknowledgement

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Program

Time	Name	Title	Affiliation
9:00	Giorgio Metta	Ten years of the iCub project	Istituto Italiano di Tecnologia, iCub Facility
9:20	Nikos Tsagarakis	Recent advancements on the compliant humanoid COMAN development	Istituto Italiano di Tecnologia, ADVR
9:40	Francesco Nori	Optimal Whole Body Control of the iCub humanoid	Istituto Italiano di Tecnologia, RBCS
10:00	Francesco Becchi	Industrial perspectives of the iCub technology	Telerobot, Concept Labs
10:20	Coffee break		
10:50	Sylvain Calinon	Learning by imitation and exploration with the COMAN and iCub humanoid robots	Istituto Italiano di Tecnologia, ADVR
11:10	Stefan Wermter	Sound Source Localization and Multimodal Integration with the iCub head	University of Hamburg, Department of Computer Science Knowledge Technology
11:30	José Santos-Victor	Experiments with the iCub: modelling oculo-motor control and understanding object affordances	IST, Institute of Systems and Robotics
11:50	Peter Ford Dominey	Cooperation with iCub	INSERM Stem Cell and Brain Research Institute, Robot Cognition Laboratory
12:10	Jun Tani	Incorporating with stochastic processes and deterministic chaos in learning to model fluctuated	KAIST, Cognitive Neuro-Robotics Lab
12:30	Lunch		
14:00	Karinne Ramírez Amaro	iCub@ICS-TUM: Semantic Reasoning, Constrained Manipulation and Humanoid Vision enable on the iCub	TU Munchen, Institute for Cognitive System
14:20	Jan Peters	TBA	TU Darmstadt, Computer Science Department
14:40	Angelo Cangelosi	Embodied Language Learning in the iCub: From First Words to Numbers	University of Plymouth, School of Computing and Mathematics
15:00	Jochen Steil	iCub goes interaction	Universität Bielefeld, Cognitive Robotics and Learning
15:20	Coffee break		
15:50	Nicolas Sommer	Tactile exploration with the iCub robot	EPFL, Learning Algorithms and System Laboratory
16:10	Patricia Shaw	A Psychologically Inspired Approach to Developmental Learning in Cognitive Robots	Aberystwyth University, Intelligent Robotics
16:30	Serena Ivaldi	iCub learning from humans via multimodal, physical, social and natural interaction	TU Darmstadt, Intelligent Autonomous Systems Lab
16:50	Zhang Chong	Simultaneous learning of vergence and smooth pursuit through active efficient coding	Hong Kong University of Science and technology
17:10	Workshop ends		

19:30	Speakers' dinner

Abstracts

Industrial perspectives of the iCub technology

Francesco Becchi – Telerobot labs

The FP6 EU funded Robotcub project had as one of its major outcomes the development of the child sized humanoid platform: the iCub. It was a large effort in the integration of earlier robotic experiences for the first time converging into a coherent platform and merged with a rigorous industrial approach. Thanks to the open source implementation and to the continuous contribution from several research groups led by IIT (Istituto Italiano di Tecnologia) the iCub platform evolved over the past decade. While on the one hand most of the iCub community focuses on the human-robot cooperation in service, assistance and, perhaps, "smart" factory scenarios, on the other hand, Telerobot labs is fostering a short to mid-term vision by reusing iCub technology for teleoperation in harsh environments. In this talk, we review some of this work in the nuclear field. Activities in the so-called hot-cell manipulation and nuclear plant decommissioning show a different perspective of the application of technologies and skills developed on the iCub.

Learning by imitation and exploration with the COMAN and iCub humanoid robots

Sylvain Calinon -Istituto Italiano di Tecnologia, IDIAP

Robot programming by demonstration facilitates the transfer of skills by letting the robot observe the user executing the task, or by kinesthetically guiding the robot through the task. This teaching mechanism is particularly relevant to humanoids applications, where the robot needs to generalize skills from very small training sets, while reproducing natural movements that are safe for the users in proximity or collaborating with the robot. One key requirement to achieve such goal is to find a representation of skills that is not limited to a single path to follow, but that instead encapsulates notions of variability, synergies, sensorimotor couplings and compliance. Such representation needs to take into account the varying constraints of the task. It also needs to be parsimonious to be shared by other learning strategies such as stochastic optimization and self-improvement. I will present our ongoing work in this direction at the Learning & Interaction Lab, Italian Institute of Technology (IIT), applied to the COMAN and iCub humanoid robots.

Embodied Language Learning in the iCub: From First Words to Numbers

Angelo Cangelosi - University of Plymouth, School of Computing and Mathematics

Growing theoretical and experimental research on action and language processing and on number learning and space representation clearly demonstrates the role of embodiment in cognition and language processing. In psychology and neuroscience this evidence constitutes the basis of embodied cognition, also known as grounded cognition (Pezzulo et al. 2012). In robotics, these studies have important implications for the design of linguistic capabilities in cognitive agents and robots for human-robot communication, and have led to the new interdisciplinary approach of Developmental Robotics (Cangelosi & Schlesinger 2014). During the talk we will present example of developmental robotics models and results from iCub experiments on the embodiment biases in early word acquisition studies, on word order cues for lexical development and number, gesture and space interaction effects. The presentation will also discuss the implications for the "symbol grounding problem" (Cangelosi, 2012) and how embodied robots can help addressing the issue of embodied cognition and the grounding of symbol manipulation use on sensorimotor intelligence.

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Cooperation with iCub

Peter Ford Dominey - INSERM Stem Cell and Brain Research Institute, Robot Cognition Laboratory

The ability to participate in cooperative activities is a hallmark of human cognition. Humans use various communication channels including language, pointing and gaze, in order to negotiate and coordinate cooperative activity. We have focused on the cognitive – perceptual mechanisms that appear to be used for cooperation in humans, and then implemented these mechanisms in cognitive systems for the iCub. An interesting development in our work is the discovery that to truly engage in such cooperative activities, humans enter into self-other relations. This motivates the investigation of the cognitive bases for the development of self in the iCub. The paper will present progress we have made in these areas

iCub learning from humans via multimodal, physical, social and natural interaction: experiments

Serena Ivaldi - TU Darmstadt, Intelligent Autonomous Systems Lab

In this talk I will present some of the experiments that we performed with the iCub in ISIR (CNRS & UPMC-Paris6), in the context of projects MACSI, EDHHI and CODYCO. In the last three years, we investigated how we can make the robot exploit multi-sensory sources to learn actively from exploration and human interaction. We focused on multimodal learning, with the idea that robot's knowledge should be built from its own sensori-motor experience in a bottom-up direction, while social guidance should provide a top-down supervising signal. We implemented a mechanism that combines intrinsic motivation and social guidance that allows the robot to learn the properties of objects while compensating the biased or unbiased supervision of the human partner. We improved dyadic interaction focusing on verbal and non-verbal cues. We tested multimodal action/perception modules in different human-robot interaction scenarios, with robotics and non-robotics expert volunteers interacting with the robot. In particular, multimodality is crucial to understand human behaviour and intention during physical and social interaction with the robot. I will conclude the talk with an overview of the research activities of ISIR about whole-body control of iCub.

Ten years of the iCub project

Giorgio Metta - Istituto Italiano di Tecnologia, iCub Facility

In this introductory talk to the workshop I will cover the history of the iCub project especially detailing the initial phases of the project and its evolution over ten years of life. I will also show some of the latest research being conducted at IIT. Finally I will show the first design of the next iCub (3.0). I will draw some conclusions about the value of Open Source in research and for the robotics community in general.

Optimal Whole Body Control of the iCub humanoid

Francesco Nori - Istituto Italiano di Tecnologia, RBCS

In this talk we will present recent advances in the whole-body control of the iCub humanoid. The iCub, initially designed for crawling and manipulating, has been recently upgraded with legs quipped with series elastic actuators. This design has been inherited from the COMAN humanoid which is itself a derivation of the iCub platform. This talk will present recent advances with specific focus on locally optimal policies for whole-body coordination in presence of multiple concurrent tasks organized in a prioritized stack.

iCub@ICS-TUM: Semantic Reasoning, Constrained Manipulation and Humanoid Vision enable on the iCub

Karinne Ramirez-Amaro, Ewald Lutscher, Andreas Holzbach and Gordon Cheng - TU Munchen,Institute for Cognitive System

The main goal of the Institute for Cognitive Systems at the Technical University of Munich, is the proper integration of Science, Engineering and Society in order to “understand through Creating”. In other words, we are developing new methods and algorithms to generate rational, social and intelligent behaviours for robotics systems such as the iCub. Therefore, we validate our contributions using the iCub platform principally because the strong humanoid design of the iCub gives us an appropriate testing platform to show similarities between the observed human motions and the robots execution. This means that our robotic system has new capabilities.

A Psychologically Inspired Approach to Developmental Learning in Cognitive Robots

Patricia Shaw - Aberystwyth University, Intelligent Robotics

Infants demonstrate remarkable talents in learning to control their sensory and motor systems. In particular the ability to reach to objects using visual feedback requires overcoming several issues related to coordination, spatial transformations, redundancy, and complex learning spaces. A major challenge in robotics is the ability to learn, from novel experiences, new behaviour that is useful for achieving new goals and skills. Autonomous systems must be able to learn solely through the environment, thus ruling out a priori task knowledge, tuning, extensive training, or other forms of preprogramming. Learning must also be cumulative and incremental, as complex skills are built on top of primitive skills. Additionally, it must be driven by intrinsic motivation because formative experience is gained through autonomous activity, even in the absence of extrinsic goals or tasks. In our work we have produced a model of longitudinal development that covers the full sequence from blind motor babbling to successful grasping of seen objects [3]. This includes the learning of saccade control, gaze control, torso control, and visually elicited reaching and grasping in 3D space. We have developed robotic implementations inspired by the learning behaviour of human infants and applied them to an iCub humanoid robot. Constraints are used to shape learning, and a schema memory system for the learning of sensorimotor experiences. The robot's representation of space is extended by learning how movements of the torso affect gaze space, and a schema learning system acts as a play generator, initiating pro-active behaviour upon sensorimotor stimulation without the need for goals. Continuing the development is the application of cognitive psychology to learning the physics of objects, and object interactions leading to learning how objects can be used as tools. Alongside this, we plan to investigate the scaffolding of learning through non-verbal interaction with a carer.

Tactile exploration with the iCub robot

Nicolas Sommer - EPFL, Learning Algorithms and System Laboratory

Tactile sensing is of utmost importance for humans, especially for manipulation and interaction with unknown environment. We think that it is also necessary for robots to make use of tactile sensing in order to master new skills and to fit human-centred environments. New technologies and hardware are now available to increase the sensing capabilities of robots, but algorithms, controllers or frameworks that allow making full use of them are still missing. In order to emphasize the importance of tactile sensing, we designed experiments where it was the only sensing modality available to the robot besides proprioception. In a first experiment, iCub learned to recognize a few human-like faces by gently tracing their contours with its fingertips, and building models of each face as time-series with Hidden Markov Models. However, the exploration of more complex surfaces or objects, especially to be able to access the objects from different angles is limited by the workspace of the iCub robot. For this reason, a method to explore an object with the two hands of iCub was developed: while one hand is holding the object, the other hand explores it from one end to the other, assuming a principal axis along which to move. After each scanning motion, the relative orientation between the exploring hand and the object's principal axis is changed so that another part of the object is accessible from the fingers equipped with tactile sensors. However, the problem of the local motion of the fingers on the object, depending on the sensed information (contact, but also additional haptic properties such as friction or hardness) and the current hand configuration has not been tackled yet. Other aspects should also be taken into account: hand kinematics, the shape of the object and the task of exploration itself. Besides, most work with tactile sensing on the hands only considers fingertip sensors and for this reason, mostly fingertip-centred algorithms are developed. In order to quickly haptically explore bigger areas, the use of the rest of the fingers and the palm is also necessary.

iCub goes interaction

Jochen Steil - Universität Bielefeld, Cognitive Robotics and Learning

We review a longer history of projects at Bielefeld University that focused and still focus on the realization of interaction abilities in the visual, auditory, cognitive and motor domains. Within the FP7-iTalk, iCub was equipped with accoustic packaging in order to understand what is important in the demonstration of actions and its reactive capabilities were investigated in user studies. In the recently finished FP7-AMARSi, the active compliance on iCub has been used for kinesthetic teaching to learn complex bi-manual actions, or pointing in 3D. Also high-level reward-based neural interactive learning has been realized to learn associations between actions and delayed rewards. Finally and most recently, we have introduced life-long learning of a motion primitive library to segment and compose complex movements from demonstration. Alltogether, iCub has become increasingly interactive through these projects in Bielefeld and has thereby become a versatile tool to investigate human-robot interaction.

Incorporating with stochastic processes and deterministic chaos in learning to model fluctuated

Jun Tani - KAIST, Cognitive Neuro-Robotics Lab.

Time-developments of physical systems are often observed as noisy or stochastic. However, it is not trivial to guess from where the stochasticity has originated just from the observation. If the observers assume that the phenomena are probabilistic, model estimation based on probabilistic model can be performed. By partitioning the state space of the system into a finite set of discrete states with labels, probabilistic state transition models can be acquired by counting events of each state transition. However, it is still possible to argue that the observed phenomena are just "pseudo stochastic" and that they are actually generated deterministically by means of the initial sensitivity characteristics of chaos which is mechanized in the original continuous state space. Although there has been a dichotomy between determinism and non-determinism of allowing probability in modeling complex phenomena, such dichotomy may not be essential when biological brains or artificial cognitive agents attempt to develop internal models of the world from accumulation of direct observation or perceptual experiences. If deterministic chaos or stochastic noise is necessary to model a set of observed phenomena, such mechanisms could be self-organized in the course of developing the model rather than given a priori in either way. The self-organized mechanism could turn out to be a merging of deterministic chaos and stochastic noise. In this talk I discuss how these two can incorporate in developing effective models to account for observed temporal phenomena by introducing a novel dynamic neural network model. Some related neurorobotics experiments are also introduced.

Recent advancements on the compliant humanoid COMAN development

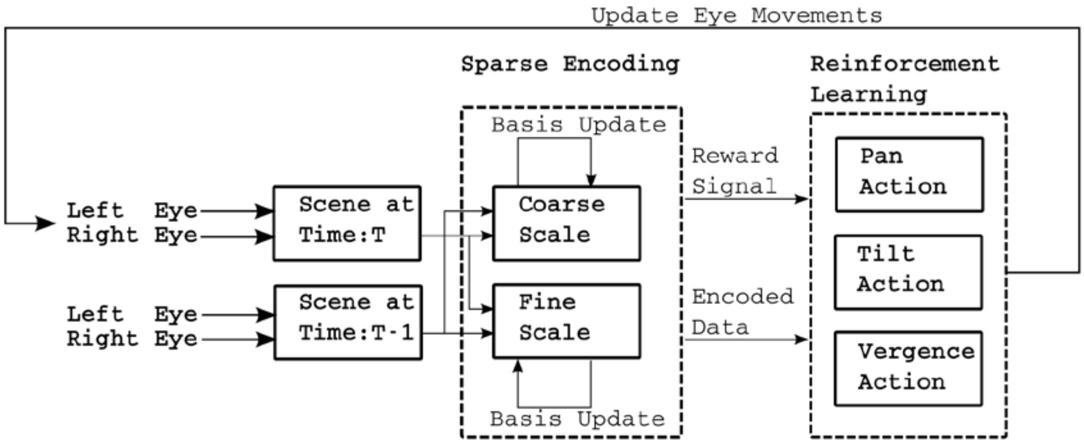
Nikos Tsagarakis - Istituto Italiano di Tecnologia, ADVR

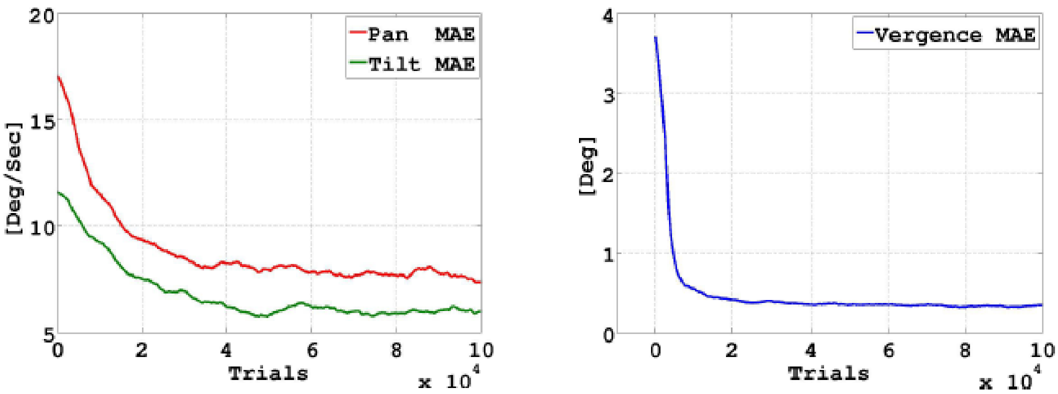
The talk will report on some of the activities that are currently or recently carried out on the further development of compliant humanoid COMAN. At the hardware side it will present ongoing work on the COMAN hardware focusing on the integration of the forearm/hand and head subsystems to form a complete humanoid platform. From the motion control perspective the talk will present and discuss recent developments and results in locomotion, and body balancing control that allow COMAN to cope with disturbances arising from push perturbations or terrain variations.

Simultaneous learning of vergence and smooth pursuit through active efficient coding

T. N. Vikram, C. Teulière, C. Zhang, B. Shi and J. Triesch - J.W. Goethe University, FIAS

In this work, we propose a system for the joint learning of smooth pursuit and vergence eye movements based on an extension of the efficient coding hypothesis to active perception. While it is widely believed that biological vision systems are adapted to encode visual information from the natural environment efficiently, e.g. Simoncelli and Olshausen (2001), we have recently proposed an approach extending the efficient coding principle to active perception (Zhao et al., 2012; Lonini et al., 2013; Zhang et al., 2014). Here we propose a computational model implemented on the iCub robot which simultaneously learns vergence eye movements and smooth pursuit behavior based on this extension of efficient coding to active perception and is fully self-calibrating. Our architecture combines a sparse coding stage with an intrinsically motivated form of reinforcement learning where a measure of the system's coding efficiency serves as a reward signal for learning active perception behavior. A spatio-temporal scene is efficiently encoded when the successive images which the two eyes sense in their foveal regions are highly similar and therefore redundant. This theme is central to our approach, and the pipeline of our architecture is given in the figure below. It closely resembles our previous works on learning of vergence eye-movements (Zhao et al., 2012; Lonini et al., 2013) and smooth pursuit (Zhang et al., 2014) and comprises a modular reinforcement learning architecture. The architecture was realized within the iCub simulator environment.





The plot in the left shows the mean average error (MAE) for Pan and Tilt velocities, the one in the right shows the MAE for the Vergence angle, when tested on the iCub simulator. The system is effective in autonomously learning accurate smooth pursuit and vergence behavior based on its efficient coding objective.

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Sound Source Localization and Multimodal Integration with the iCub head

Stefan Wermter, Johannes Bauer, Jorge Davila Chacon - University of Hamburg, Department of Computer Science Knowledge Technology

Humans localize objects mostly using vision and hearing. They do so with remarkable accuracy and speed and it has been shown in psychophysical experiments that they integrate visual and auditory localization very well. We develop models of natural bio-inspired uni-sensory and multi-sensory localization, with a particular focus on their development. One of the goals is to better understand object localization in humans. The other goal is to use the knowledge we gain to improve multi-sensory integration in robots and especially in humanoid robots, which share part of our sensory world and thus have to solve similar problems. We validate our research in neuro-robotic experiments. Using an audio-visual robotic virtual reality lab, we present our iCub robotic head with dynamic cross-sensory stimuli. We use these stimuli to train our models and to study their behavior in terms of performance and resemblance to their biological counterparts on the neurophysiological and psychophysical level.

Experiments with the iCub: modelling oculo-motor control and understanding object affordances

José Santos-Victor - IST, Institute of Systems and Robotics

I will describe some of the experiments we have carried out with the iCub and how they can help us understanding several aspects concerning human cognition. One set of examples will be devoted to the coordination of gaze movements with arm reaching and grasping movements. I will illustrate how data extracted from human subjects can be used to model the interplay between different biologically plausible control loops. In the second part of the talk I will briefly describe how we have used the iCub to learn and explore object affordances and how the affordances can be used as a construct for higher-level cognitive skills.

Additional speakers:

- **Jan Peters - TU Darmstadt, Computer Science Department**

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