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The ITALK project: Integration and Transfer of Action and Language Knowledge in Robots

Angelo Cangelosi*, Tony Belpaeme, Giulio Sandini, Giorgio Metta, Luciano Fadiga, Gerhard Sagerer, Katherina Rohlfing, Britta Wrede, Stefano Nolfi, Domenico Parisi, Chrystopher Nehaniv, Kerstin Dautenhahn, Joe Saunders, Kerstin Fischer, Jun Tani and Deb Roy
* University of Plymouth
A316 Portland Square, PL4 8AA Plymouth, United Kingdom
+44 1752 232559
angelo.cangelosi@plymouth.ac.uk

ABSTRACT
This short paper presents the ITALK project, which aims to develop artificial embodied agents able to acquire complex behavioural, cognitive, and linguistic skills through individual and social learning. ITALK is a large-scale integrated project funded by the European Union under the 7th Framework.

1. INTRODUCTION
ITALK is a recently started 4-year project involving the University of Plymouth, the Italian Institute of Technology in Genoa, the University of Bielefeld, the Institute for Cognitive Science and Technology in Rome, the University of Hertfordshire, the University of Southern Denmark, the RIKEN Brain Science Institute and the Massachusetts Institute of Technology.

The project intends to develop cognitive robotic agents, based among others on the iCub humanoid platform, that learn to handle and manipulate objects and tools autonomously, to cooperate and communicate with other robots and humans, and to adapt their abilities to changing internal, environmental, and social conditions.

The main theoretical hypothesis behind the project is that the parallel development of action, conceptualisation and social interaction permits the bootstrapping of language capabilities, which on their part enhance cognitive development. This is possible through the integration and transfer of knowledge and cognitive processes involved in sensorimotor learning and the construction of action categories, imitation and other forms of social learning, the acquisition of grounded conceptual representations and the development of the grammatical structure of language.

The project will lead to the development of: (a) new theoretical insights, models and scientific explanations of the integration of action, social and linguistic skills and in particular on the hypothesis that action, social and linguistic knowledge co-develop and further bootstrap cognitive development, (b) new interdisciplinary sets of methods for analysing the interaction of language, action and cognition in humans and artificial cognitive agents, (c) new cognitively-plausible engineering principles and approaches for the design of robots with behavioural, cognitive, social and linguistic skills.

Overall, the project sets out to do visionary research that will provide a new standard in embodied cognitive science and will demonstrate the effectiveness of the method proposed by integrating interdisciplinary theoretical and experimental research on a single advanced robotic platform.

2. CORE RESEARCH ISSUES
The research in ITALK falls into five main research themes: (i) action development, (ii) conceptualisation, (iii) social interaction, (iv) language emergence, and (v) integration and bootstrapping of cognition.

The study of the development of complex action manipulation capabilities will –in contrast to existing approaches– be based on synchronous development of motor, social and linguistic skills. For this it is fundamental to identify the characteristics of action development that are compatible with this scenario and reject those that are mere engineering solutions. Two core properties of biological motor control systems will be considered: compositionality, the construction of hierarchically ordered gesturing and manipulation, and generalization. We will study how action development can be guided by individual exploration by the robot and by imitating humans.

A fundamental skill of any cognitive system is the ability to produce a variety of behaviours and to display the behaviour that is appropriate to the current individual, social, cultural and environmental circumstances. This will require agents (1) to reason about past, present and future events, (2) to mediate their motor actions based on this reasoning process and (3) to communicate using a communication system that shares properties with natural language. For this agents will need to develop and maintain internal categorical states, i.e. ways to store and classify sensory information. We term such internal states *embodied concepts* and we understand them as representations grounded in sensory-motor experiences that identify crucial aspects of the environment and/or of the agent/environmental interaction.

Another essential component of the research project is to look at the role of social learning and social interaction to support the development of a shared linguistic communication system. In particular, new research will consider (i) the role of imitation and human-robot interaction for the acquisition of shared communication systems based on deixis, gestures and reference, (ii) the role of users' expectation in human-robot interaction and (iii) the emulation of actions and gestures in the learning of multimodal task-oriented behaviour. Such research will be based on a series of human-robot interaction (HRI) experiments and on observational studies on parent-child dyads which will inform robot-robot and human-robot experiments. We expect to extend

the expertise and methodologies in dialog systems for HRI studies to new studies on social interaction and communication where the robot's linguistic communication system develops through interaction with its environment and other robots and humans.

The project will follow a cognitive linguistics approach. As it is centred on the interaction between action and language development, it provides the ideal testbed to investigate the emergence of linguistic constructions in close interaction with the development of action, social and grounded conceptual capabilities. We will focus on the emergence of linguistic structure. Among the research issues include (i) generalisation as the basis of the emergence of symbolic systems, (ii) the role of speech and "acoustic packaging": speech or sound signals which serve as a cue to aid the learning of action sequences, (iii) the role of constructional grounding: the acquisition of linguistic construction and how one construction become favoured over another, (iv) the ontogenetic emergence of compositional lexicons, and (v) evolutionary studies on language emergence.

Theoretical and experimental evidence on the relationship between motor, social and language learning highlights the importance of a strong interaction and co-dependence between these cognitive capabilities. Such a strict interaction results in the bootstrapping of the agent's cognitive system. For example, through the transfer of action knowledge to linguistic representations and vice versa. Some of the specific areas of scientific and technological investigation on language/action/ cognition that will be considered during the project will be: (1) the motor and affordance basis of language categories and the role of action knowledge in language processing, (2) the involvement of mirror-neuron system in action observation and imitation for communication via gaze sharing and (3) the role of language as a tool to enhance cognition.

Figure 1. the iCub humanoid will be used as experiment platform in ITALK.

3. TECHNOLOGIES

The research will be integrated and tested in new robotic models of language and cognitive development. Robotic experiments and demonstrations will be primarily based on the iCub humanoid robot (www.robotcub.org, figure 1). iCub is an open-source robotic platform shaped as a child-like humanoid robot, the size of a three year old. The iCub has 53 degrees of freedom in the head, arms, hands and legs. When appropriate we will use simulation models of embodied cognitive agents capable of object manipulation and communication.

4. OBJECTIVES

The project has four objectives which will be realized over the coming four years:

- Provide new theoretical insights, models and scientific explanations of the integration of action, social and linguistic skills and in particular on the hypothesis that action, social and linguistic knowledge co-develop and further bootstrap cognitive development.
- Develop an interdisciplinary set of methods for analyzing the interaction of language, action and cognition in humans and artificial cognitive agents using robot learning experiments, computer simulations, cognitive linguistic analysis, and experimental investigations from developmental linguistics, the neuroscience of language and action, and human-robot interaction experiments.
- Develop innovative and cognitively plausible engineering principles, techniques and approaches for the design of communicative and linguistic capabilities in cognitive robots able to interact with their physical and social world and to manipulate entities, artefacts and other agents including humans.
- Demonstrate the effectiveness of the above scientific and technical advances through the use of robotic experiments on the acquisition of object manipulation, social skills and linguistic capabilities in simulated and physical cognitive robots. In particular, robotic agents will be able to (a) acquire complex object manipulation capabilities through social interaction; (b) develop an ability to create and use embodied concepts; (c) develop social skills that allow flexible interaction with other agents or people; (d) develop linguistic abilities to communicate about their interaction with the world.

5. ACKNOWLEDGMENTS

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