The Power of Prediction: Robots that Read Intentions

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Abstract— Humans are experts in cooperating in a smooth and proactive manner. Action and intention understanding are critical components of efficient joint action. In the context of the EU Integrated Project JAST [16] we have developed an anthropomorphic robot endowed with these cognitive capacities. This project and respective robot (ARoS) is the focus of the video. More specifically, the results illustrate crucial cognitive capacities for efficient and successful human-robot collaboration such as goal inference, error detection and anticipatory action selection. Results were considered one of the ICT "success stories"[22].

I. INTRODUCTION

Humans are remarkably efficient in cooperating with their fellow human beings. Recent studies of the neurocognitive basis of cooperative task performance show that understanding the actions and intentions of one's partner is an important component of this social capacity ([1-7], see also [8-12]). To be successful in complex social interactions, we need to understand what our partner is after, i.e., what her or his intentions are. This implies that we not only have to recognize the *immediate* goal of the ongoing behavior of the partner with whom we collaborate but also infer what the *final* goal of our partner's action sequence is. The latter is particularly challenging if we realize that we may only perceive an initial fragment of our partner's action sequence. A second critical ingredient to fluent cooperation is the ability to detect whether or not the actions performed by oneself or one's partner are deviating in any way from those which would be expected based on the inferred intentions and, if such a discrepancy is noted, to repair, or formulate suggestions on how to repair, such errors.

As robot systems are moving as assistants into human everyday life, the question of how to design robots capable of acting as sociable partners in collaborative joint activity is

becoming increasingly important [13-15]. Useful and efficient human-robot interaction requires that both teammates coordinate and synchronize their actions and decisions in any given shared task. In order to decrease the workload of the human and to increase user satisfaction, the robot should contribute equally to this coordination effort. This means that, like the human counterpart, the robot should exhibit high-level cognitive capacities such as intention recognition and action understanding.

In an interdisciplinary effort involving cognitive scientists and roboticists (EU Integrated Project JAST [16]) we have developed an autonomous anthropomorphic robot that integrates in its control architecture known neurocognitive mechanisms supporting cooperative task performance in humans [1, 17-21]. This endeavor was considered one of the "success stories" of the Scientific and Technological Research in Europe (e.g. see "JAST-Robots get power of predictions" in [22]). This project and respective robot (ARoS) is the focus of the video.

II. COGNITIVE ARCHITECTURE FOR JOINT ACTION AND TASKS

The key idea is that the observer performs an internal motor simulation to predict the consequences of perceived actions using knowledge of his or her actions and motor intentions. During joint action, the representation of the inferred goal of the co-actor together with representations of prior task knowledge may then automatically bias the observer's decision process towards selecting an adequate complementary behaviour. In line with this hypothesis, the findings of a recent behavioural study suggest that the perception-action coupling appears to be indeed to some extent under the control of task and goal representations [6,1,5].

The robot control architecture for human-robot collaboration implements such a context-sensitive, i.e. flexible, mapping between action observation and action execution (Fig. 1). The coordination of actions and decisions among the teammates is modeled as a dynamic process that builds on the continuous integration of input from representations of the inferred goal of observed actions (obtained through motor simulation), contextual cues (e.g., location of objects in the scene) and shared task knowledge (e.g., assembly plan). The representation of the complementary action that gets the strongest support will win the dynamic competition process among all possible complementary behaviours. As a

*Research supported by EC through EU Integrated Project "JAST: Joint-Action Science and Technology" (Ref. IST-2-003747-IP). Contact: estela.bicho@dei.uminho.pt

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theoretical framework we use dynamic neural fields [23]. For a discussion with other approaches see [17-21].

The robot was tested in different joint action scenarios and different human users (Fig. 2).

Fig.1 Schematic view of the cognitive architecture for joint action (for details see [17, 18, 20]). It implements a flexible mapping from observed actions (layer AOL) onto complementary actions (layer AEL) taking into account the inferred action goal of partner (layer IL), detected errors (layer EML), contextual cues (OML) and shared task knowledge (CSGL). The goal inference capacity is based on motor simulation (layer ASL).

Fig.2 Human-robot teams and different scenarios for joint action.

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