Modelling and control for Human–Robot Interaction: physical and cognitive aspects

Agostino De Santis

Index Terms— **Unifying characteristics in Human–Robot Interaction (HRI), properties of novel and synergistic research in HRI.**

I. Introduction

In this short paper, some contributions for research in Human–Robot Interaction (HRI) are outlined. Possible answers are reported to the questions suggested for the NEWHRI workshop, summarized in the reported keywords. A more comprehensive discussion on contributions which fit in the proposed research framework for the workshop can be found in the listed bibliographical references.

The next generation of robots, both for service or cooperative work, is expected to interact with people more directly than today. Human–Robot Interaction will certainly happen at the cognitive level (cHRI), fundamentally due to mental models of HRI, and concerning communication between human and robot. However, robots are distinct from computers or other machines: they physically embody the link between perception and action, whose "intelligent connection" is a definition for robotics, and often have an anthropomorphic appearance. At the same time, they generate force and have a "body": hence, the most revolutionary and challenging feature of the next generation of robots will be physical Human-Robot Interaction (pHRI) [1].

In pHRI, humans and robots share the same workspace, come in touch with each other, exchange forces, and cooperate in doing actions on the environment. This approach is affordable if robots can be considered service tools (according to a "Western" approach), which guarantee human safety and autonomy. An effort is keeping the "physical" viewpoint while considering the importance of inferences and evaluation on unstructured environments. This viewpoint influences the new paradigms for the design and control of robot manipulators. Notice also that, right now, a sort of Descartes "dualism" leads to accepting a dichotomy: the "brain" of robotic systems is usually studied by computer scientists and neuroscientists, whereas the study of mechanisms and their control is assigned to cybernetics, electronic, and mechanical engineers.

Cognitive and physical interaction, however, are not independent: physical interaction can help in setting rules for cognitive evaluations of the environment during interaction tasks, while cognitive aspects may improve the physical interaction by setting a number of suitable control parameters. The awareness of the complementarity between pHRI and cHRI is an important point for researchers in the field.

II. The physical viewpoint and PHRIENDS

Robots designed to cooperate with humans must fulfil different requirements from those typically met in conventional industrial applications. Typical conventional robot systems and applications require fast motions and absolute accuracy, without external sensing, provided that the operational environments are perfectly known. The most important change of perspective is related to the optimality criteria for the considered manipulators: safety and dependability are the keys to a successful introduction of robots into human environments [2]. Only dependable robot architectures can be accepted for supporting "human-in-the-loop" conditions and human-robot teams, and the safety of humans cooperating with robotic systems is the main need for allowing pHRI.

Therefore, intrinsic safety, together with the legibility of robot motion behaviours can be a unifying optimality criterion to be pursued. In addition, physical safety has to be complemented by the "mental safety", i.e., by the awareness of robot motion, avoiding scaring postures and abrupt movements.

The on-going European project Physical Human–Robot Interaction: Dependability and Safety (PHRIENDS) [3] has the mission of developing key components of the next generation of robots, designed to share the environment and to physically interact with people, meeting safety standards while delivering useful performance: this poses new challenges to the design of all components of the robot, including mechanics, control, planning algorithms and supervision systems, sensing.

Safety has many levels: compliance of the robot in case of contact, fast monitoring of the scene, precise collision checks with emergency stops. We can therefore consider 3 steps for safety tactics: those related to intrinsic safety, those which can prevent collisions, and those which are

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A. De Santis is with PRISMA Lab, DIS, Università di Napoli Federico II, Italy, agodesa@unina.it

activated in the event of a crash. The second step in the proposed approach is addressed more in depth in [4], [5], providing a manipulator's and world's model for fast deliberative/reactive motion, with arbitrary control points on the robot and the possibility of combining different trajectories for the fulfilment of different tasks, to be specified at a higher level.

In detail, since pHRI has the two complementary directions of intrinsically safe (future) robots and safe by control (current) robots, the proposed contribution can be considered useful for completing the safety tactics for a service manipulator, and constitute a modelling basis for multiple-point control. The role of planning and control is evident both in cHRI and pHRI: while legible motion and smoothness of movements have also cognitive relevance, the possibility of having a very fast modelling and control of the interaction environment is a key issue for quickly detecting and moving interacting robots, giving control to different interfaces and control approaches at the same time. Among the main aspects, the necessity of controlling multiple point of a robot in pHRI is central, both for multiple input channels to a robotic assistant (impedance control, safety tactics, teleoperation, emergency paths), and for the presence of multiple possible colliding parts [6], e.g., of a humanoid [4], [7] .

Humanoids are a special case because they intrinsically present multiple control points for grasping, moving the head for perception, assuming postures, walking, balancing, and so on. Finally, whole-robot motion behaviour via multiple point control and reactive motion has to be cast into a task management policy, in order to complete a robot model for interaction.

III. Summary of possible contributions and points for the discussion

Summarizing, a collection of results related to the modelling/control aspects is reported in [8], with emphasis on:

- environment modelling for simple geometric computation,
- multiple-point approach both for multiple inputs and multiple outputs of the robot,
- arbitrary selection of the control points on the robot,
- reactive real-time control for safety,
- integration with deliberative tasks and other safety tactics.

It is important to complement this research with results from the cHRI community, since modelling and control parameters can be modified on the basis of cognitive evaluations.

Moreover, there is the need for discussing synergistic activities for:

- interfaces,
- safety,
- definition of legibility of the motion,
- evaluation of acceptance,
- rules for validation,
- possible biomimetic solutions,
- contributions to international standards for HRI.

In addition, learning algorithms have to be compared for incremental knowledge acquisition.

IV. Additional aspects

Synergies for promoting HRI in the robotics community are currently represented by joint research projects and special conferences or dedicated tracks in the main conferences.

In order to foster common researches on HRI, common benchmarks and test environments have to be introduced.

As an example, for human-robot cooperation, the DLR-III manipulator [9] is a promising platform, due to lightweight design and implemented safety tactics, developed also in the framework of the European project PHRIENDS (www.phriends.eu) [3]. It is worth citing the important research activity in the so-called "soft robotics" concepts introduced and developed by DLR [10].

Moreover, the importance of realistic simulation (like, e.g., Virtual Reality-VR) has to be investigated and compared with experiments.

The role of the networks and associations, such as the IEEE Robotics and Automation Society, is an interesting point for the discussion: the society already has a number of committees which can provide links for cooperation in HRI.

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