Toward Coactivity

Matthew Johnson[1], Jeffrey M. Bradshaw[1], Paul J. Feltovich[1], Catholijn Jonker[2], Maarten Sierhuis[3], & Birna van Riemsdijk[2]

[1]Florida Institute for Human and Machine Cognition
Pensacola, Florida, USA
{mjohnson, jbradshaw, pfeltovich}@ihmc.us

[2]EEMCS, Delft University of Technology
Delft, The Netherlands
{c.m.jonker, m.b.vanriemsdijk}@tudelft.nl

[3]NASA Ames Research Center
Moffett Field, California, USA
msierhuis@mail.arc.nasa.gov

***Abstract*— This paper introduces the concept of *Coactivity* as a new focal point for Human-Robot Interaction to address the more sophisticated roles of partner or teammate envisioned for future human-robot systems. We propose that most approaches to date have focused on autonomy and suggest that autonomy is the wrong focal point. The envisioned roles, if properly performed, have a high level of interdependence that cannot be addressed solely by autonomy and necessitate a focus on the *coactivity*.**

Keywords- coactive, coordination, autonomy, interdependence

I. INTRODUCTION

The Human-Robot Interaction (HRI) community is inspired by the vision of robots becoming part of people's everyday lives with expected roles such as caretaking assistants for the elderly, medical assistants, day care assistants, coworkers in factories and offices, and servants in our homes. These exemplar roles showcase the importance of robots transitioning from common roles of today, where they are frequently no more than teleoperated tools, to much more sophisticated partners or teammates.

The past decade has seen a tremendous increase in fielded mobile robotic systems; however, these systems are very different from the exemplar roles described above. Researchers have been investigating the middle ground between fully autonomous and fully teleoperated systems under various names including mixed-initiative [1], adjustable autonomy [2], and collaborative control [3]. As the names suggest, these approaches understand that the ideal is not a fixed location but may vary. These approaches and most traditional planning technologies at the foundation of intelligent robotic systems typically take an autonomy-centered approach, focusing on control and task allocation.

We suggest autonomy is the wrong focal point for addressing the new, more challenging roles for robots. These roles have a much higher commitment then other types of interaction, such as passing in a hallway or making a sales transaction with a grocery clerk. We are in no way suggesting today's robots should not have autonomy nor that work on autonomy should not continue. We are suggesting that as a community, we have been focused strongly on autonomy (maybe for good reasons) and that we will need to pause and reconsider our focus. The target of this discussion is not current teleoperated systems or systems struggling with basic autonomy. We were specifically addressing what a human-robot system would look like if it were to fill one of the roles provided (care taker, medical assistant, coworker, or servant). The envisioned roles, if properly performed, have a high level of interdependence that cannot be addressed solely by autonomy and necessitate a focus on the *coactivity*.

II. WHY AUTONOMY IS THE WRONG FOCAL POINT

Once a base level of competence is achieved, coordination of joint activity (teamwork at its simplest form) will take on an ever increasingly important role in the design of a system. This trend was noted by Allen who reported that "the only type of interactions supported by a typical state-of-the-art planning system (namely, adding a new course of action) handled less than 25% of the interactions and that much of the interaction was concerned with maintaining the communication (summarizing and clarifying, for example) or managing the collaboration (discussing the problem solving strategy) [1]." As autonomy increases, the robot has less dependence on the human, but the human has more dependence on the robot, because the robot is now the sole owner of certain information and decisions. This is an issue that cannot be addressed by more autonomy.

The second reason is the inherent frailty of autonomy. Robots, like their creators, will always be imperfect. This underlying truth necessitates human involvement at some level and accentuates the importance of teamwork. Frailty means you will have unexpected events (failures). You cannot overcome failed autonomy with autonomy, but you can with teamwork (e.g. Fong's collaborative control [3]).

A third reason is that even if frailty were not an issue, the "substitution myth [4]" reminds us that autonomy cannot be substituted for human activities without otherwise affecting the operation of the system. Similarly, Norman [5] points out that help of whatever kind does not simply enhance our ability to perform the task: it changes the nature of the task itself. Humans cannot simply offload tasks to the robots without incurring some coordination penalty. This is not a problem as long as we keep in mind that autonomy is not an end in itself in the field of HRI, but rather a means to supporting productive interaction [6].

The last reason we will discuss has to do with human nature and is probably most important. Humans are typically the desired beneficiaries of the fruits of the robot labor. We are the reason for the system and will always want access to the system. Not only do we want access to understand the system,

978-1-4244-4893-7/10/$25.00 © 2010 IEEE

but we want input to affect it. To paraphrase Kidd [7], it is not that human skill is required, but that human involvement is desired.

III. COACTIVITY

The basic premise of *coactivity* is that the underlying interdependence of joint activity is the critical design feature. Autonomous capability, while important, is secondary. The term *coactive* is specifically chosen to highlight the difference in the approach. There are three meanings [9] associated with *coactive*:

1) *Joint action*
2) *An impelling or restraining force; a compulsion*
3) *Ecology. Any of the reciprocal actions or effects, such as symbiosis, that can occur in a community.*

Joint action is about each participant being engaged in the same action. Previous work focused largely on assigning or allocating tasks to individuals. For *coactivity*, we are no longer dealing with individual *autonomous actions* but with group *participatory actions* [8]. This is a departure from the previous approaches, with the exception of Collaborative Control which began to incorporate all parties into the action (at least in the perceptual and cognitive dimensions). We extend this to all dimensions and add the reciprocal nature of each. As Clark states, "a person's processes may be very different in individual and joint actions even when they appear identical [8]." Clark's example is playing a musical solo versus playing a duet. Although the music is the same, the processes involved are very different.

The compulsion derives from the interdependence inherent in the joint task. Since the players are all participating in the task there is a collective obligation [10] even if not currently "assigned" to the task. This includes certain duties and obligations that correlate with good teamwork. Capturing these obligations is an essential part of addressing *coactivity* and a departure from previous approaches which do not address the idea of a collective obligation.

The last key feature of *coactivity* is the idea of reciprocal actions. Many of the abilities required for good teamwork required reciprocal abilities from the other team members. For example, if I need to know your status, you must be able to provide status updates. If you can help make navigation decisions, my navigation algorithm must allow outside guidance. This is another break from the individual autonomy-centered approach. When designing for *coactivity* you must consider the human-robot team not just the autonomous robot behavior.

There are several examples from recent HRI work that support our hypothesis. Fong's [3] work demonstrated supporting frail autonomy by making the obstacle avoidance activity a participatory one with matching reciprocal functionality. Stubbs [11] noted that as autonomy increases, transparency became the biggest problem in a remote rover. This is a real world example how autonomy solved some problems, but at the same time created new issues that we feel are a direct result of the *coactive* nature of the task.

IV. SUMMARY

The future vision for HRI involves many roles that will require teamwork. Autonomy, while still important should not be the primary focus. We can extend Salas' statement on human team members to robots:

> "It is not sufficient that members be technical experts – they must also be experts in the social interactions that lead to adaptive coordination action (i.e. teamwork)" [12]

Human-robot teams are about joint activity, which means there is always interdependence between the team members. This provides an implicit compulsion to engage in maintaining common ground and other aspects of teamwork. It is also important to consider the reciprocal nature of team capabilities. *Coactivity* captures these elements and provides a new approach to addressing the needs of these future systems.

REFERENCES

1. Allen, J.E., C.I. Guinn, and E. Horvtz, *Mixed-Initiative Interaction.* IEEE Intelligent Systems, 1999. **14**(5): p. 14-23.
2. Kortenkamp, D., *Designing an Architecture for Adjustably Autonomous Robot Teams*, in *Revised Papers from the PRICAI 2000 Workshop Reader, Four Workshops held at PRICAI 2000 on Advances in Artificial Intelligence*. 2001, Springer-Verlag.
3. Fong, T.W., *Collaborative Control: A Robot-Centric Model for Vehicle Teleoperation*. 2001, Robotics Institute, Carnegie Mellon University: Pittsburgh, PA.
4. Christofferson, K. and D.D. Woods, *How to make automated systems team players*, in *Advances in Human Performance and Cognitive Engineering Research, Vol. 2*, E. Salas, Editor. 2002, JAI Press, Elsevier.
5. Norman, D.A., *Cognitive artifacts*, in *Designing Interaction: Psychology at the Human-Computer Interface*, J.M. Carroll, Editor. 1992, Cambridge University Press: Cambridge. p. 17-38.
6. Goodrich, M.A. and A.C. Schultz, *Human-robot interaction: a survey.* Found. Trends Hum.-Comput. Interact., 2007. **1**(3): p. 203-275.
7. Kidd, P.T., *Design of human-centered robotic systems*, in *Human-Robot Interaction*, M. Rahimi and W. Karwowski, Editors. 1992, Taylor & Francis. p. 225-241.
8. Clark, H.H., *Using language*. 1996, Cambridge [England] ; New York: Cambridge University Press. xi, 432 p.
9. *coaction*, in *http://dictionary.reference.com/browse/coactive*.
10. Diggelen, J.v., et al., *Implementing Collective Obligations in Human-Agent Teams using KAoS Policies*, in *Proceedings of Coordination, Organization, Institutions and Norms in Agent Systems (COIN)*. 2009, Springer.
11. Stubbs, K., P. Hinds, and D. Wettergreen, *Autonomy and common ground in human-robot interaction: A field study.* IEEE Intelligent Systems, 2007(Special Issue on Interacting with Autonomy): p. 42-50.
12. Salas, E., et al., *The making of a dream team: when expert teams do best*, in *The Cambridge Handbook of Expertise*, K.A. Ericsson, et al., Editors. 2006