Coactive Design – Designing Support for Interdependence in Human-Robot Teamwork

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I. Introduction

This workshop focuses on how to best use a human supervisor in the loop to increase the overall system's performance, capabilities and robustness. Our talk will address this by discussing what it means to be "in the loop." It will also challenge the assumption that the best role for the human is that of supervisor. In fact, we would argue that use of such terminology is fairly nebulous and provides little design guidance. We will provide an alternative approach we call Coactive Design.

II. Coactive Design

Coactive Design is a method for how to design and build effective human-machine systems. The approach deviates from traditional autonomy-centered approaches because it is based on the concept of interdependence [1]. We coined the term *coactive* as a way of characterizing the activity. Besides implying more than one party is involved in the activity, the term "coactive" is meant to convey the type of involvement. Consider an example of playing the same sheet of music as a solo versus a duet. Although the music is the same, the processes involved are very different [2]. The difference is that the process of a duet requires ways to support the interdependence among the players. This is a drastic shift for many autonomous robots, most of which were designed to do things as independently as possible.

Coactive Design is about designing in a way that enables effective teamwork through support for interdependence. The goal of Coactive Design is to help designers identify interdependence relationships in a joint activity so they can design systems that support the relationships deemed appropriate. These relationships are specified in terms of three key capabilities: observability, predictability and observability. These supporting relationships provide the infrastructure necessary to achieve the objectives of coordination, collaboration, and teamwork. In a sense, they determine what it means to be "in the loop."

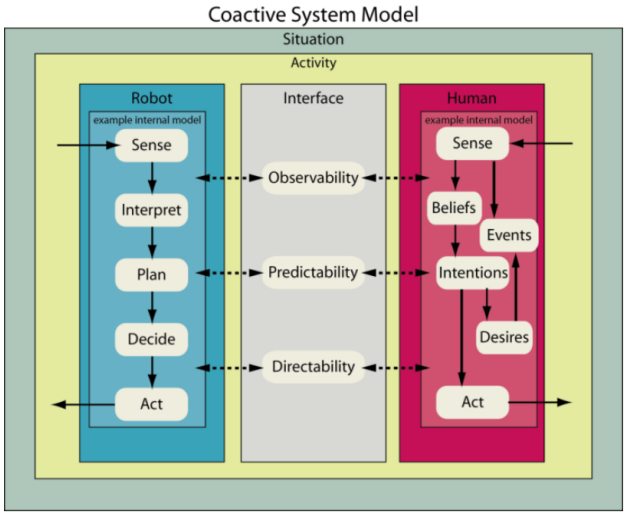

Fig. 1. Coactive System Model based on observability, predictability, and directability

As a design process, Coactive Design produces a specification that details human-robot team requirements [3]. This is also very different from using terms like "supervisor." These requirements are used to guide the implementation of *both* the algorithms *and* interface which provides the teamwork infrastructure. The sum of the capabilities provided by the teamwork infrastructure determines the runtime options which (in addition to how they are employed, the situation, and other factors) determine performance and robustness of the team.

As a use case for applying Coactive Design to humanoid operation, we will use the DARPA Robotics Challenge (DRC). The DRC is an international robotics competition. The primary goal of the DRC is to develop robots capable of assisting humans in responding to natural and man-made disasters. We competed using an Atlas humanoid robot made by Boston Dynamics. We use Coactive Design to help guide the development of our algorithms and our interface, which proved to be effective during the DRC competition. We will discuss our experiences during this competition and some lessons we learned from participating.

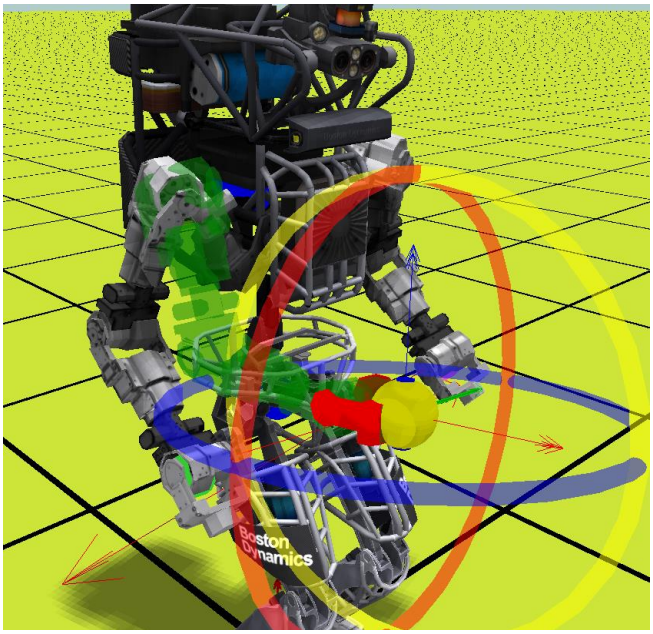

Fig. 2. Arm trajectory visualization tool on Atlas showing the reachability of the arm for a specific user-defined hand pose. The visualization tool shows the actual and desired joint configuration and color codes each joint to notify the operator whether the desired hand pose is reachable or not. Arm motion preview is also available.

III. Conclusion

In summary as experienced in both, DARPA Virtual Robotics Challenge and DARPA Robotics Trials, we believe that coactive design enables the capability for a robotic system to achieve unprecedented performance through interdependence. Helping designers to understand interdependence relationships is key in providing the basis for an effective infrastructure. Our performance in both challenges confirmed the importance of making coactive design part of the entire design process resulting in a better performing system capable of adapting quite rapidly to new system requirements and unforeseen situations during the competition.

References

[1] M. Johnson, J. Bradshaw, P. Feltovich, C. Jonker, B. van Riemsdijk, and M. Sierhuis, "The Fundamental Principle of Coactive Design: Interdependence Must Shape Autonomy," in in *Coordination, Organizations, Institutions, and Norms in Agent Systems VI*, vol. 6541, M. De Vos, N. Fornara, J. Pitt, and G. Vouros, Eds. Springer Berlin / Heidelberg, 2011, pp. 172–191.

[2] H. H. Clark, *Using language*. Cambridge [England] ; New York: Cambridge University Press, 1996, p. xi, 432 p.

[3] M. Johnson, J. M. Bradshaw, P. J. Feltovich, C. M. Jonker, M. B. van Riemsdijk, and M. Sierhuis, "Coactive design: Designing support for interdependence in joint activity," *Human Robot-Interaction*, 2014.