Understanding Team Dynamics to Facilitate Fluent Human-Robot Coordination

Tariq Iqbal and Laurel D. Riek
Department of Computer Science and Engineering,
University of Notre Dame, Notre Dame, IN, USA 46556.
e-mail: {tiqbal, lriek}@nd.edu.

I am a PhD candidate in Computer Science and Engineering at the University of Notre Dame. My research interests span areas within robotics, human-robot interaction, computer vision, and machine learning. Currently, I am working on designing and implementing models for robots to understand high-level group behaviors to produce fluent human-robot interaction.

As technology advances, the presence of autonomous robots is becoming prominent in our daily lives, and they are expected to interact with humans in teams [1]. In order to be effective teammates, robots need to be able to understand human team dynamics. This understanding will help the robots to recognize, anticipate, and adapt to human motion. Understanding human team dynamics is not trivial for robots. One of the crucial reasons for that is the limited number of available approaches for robots to detect human team dynamics accurately.

In many group interaction scenarios, humans coordinate their activities with the rest of the group, and the group eventually reaches a synchronous state [2]. How synchronously the group members perform their actions is an important behavioral indicator of group-level cohesiveness [3]. Thus, if a robot has an understanding of these underlying group dynamics, then it can anticipate future actions in a team, and adapt to those actions in order to be effective teammates.

To enable a robot to understand team dynamics, we developed a method to automatically detect the degree of synchronization of a group [4]. This method takes multiple types of discrete, task-level events into consideration while measuring the group synchrony. In addition, this method is capable of modeling synchronous and asynchronous behavior of the group. We explored this method within the context of joint action, and validated the method by applying it to a human-human, and a human-robot team [4]–[6].

Based on this work, we designed a new approach to enable robots to perceive human group behavior in real-time, anticipate future actions, and synthesize their own motion accordingly [7]–[9]. We validated this method within a human-robot interaction scenario, where an autonomous mobile robot observed a team of human dancers, and then successfully and contingently coordinated its movements to "join the dance." We compared the results of our anticipation method to move the robot with another method which did not rely on team dynamics, and found our method performed better both in terms of more closely synchronizing the robot's motion to the team, and also in exhibiting more contingent and fluent motion. These findings suggest that the robot performs better when it has an understanding of team dynamics than when it does not.

Beyond the rhythmic synchronous group interactions scenarios, there exist many group interaction scenarios where the activities performed by the group members are not only synchronous, but also change their tempo over time. In my recent work, I are exploring how robots can take advantage of the understanding of temporal adaptation and anticipation to coordinate with other external rhythms. This work will enable robots to recognize, anticipate, and adapt to human groups, as well as will help others in the robotics community to build more fluent and adaptable robots in the future.

Presenting my work at the RSS Workshop on Planning for HRI and attending RSS conference will provide a great opportunity to get feedback from a specialized research community. Receiving feedback from peers in the robotics community will help me to think deeply about how to strengthen my current approach, and explore new directions in my work.

References

[1] L. D. Riek, "Robotics technology in mental health care," *Artificial Intelligence in Behavioral and Mental Health Care*, 2015.
[2] D. R. Forsyth, *Group dynamics*, 4th ed. T. Wadsworth, 2009.
[3] M. J. Richardson, R. L. Garcia, T. D. Frank, and et al., "Measuring group synchrony: a cluster-phase method for analyzing multivariate movement time-series," *Frontiers in Physiology*, 2012.
[4] T. Iqbal and L. D. Riek, "A Method for Automatic Detection of Psychomotor Entrainment," *IEEE Transactions on Affective Computing*, 2015.
[5] T. Iqbal, M. J. Gonzales, and L. D. Riek, "Joint action perception to enable fluent human-robot teamwork," in *IEEE Int'l Symposium on Robot and Human Interactive Communication*, 2015.
[6] ——, "Mobile robots and marching humans: Measuring synchronous joint action while in motion," in *AAAI Fall Symp. on AI-HRI*, 2014.
[7] T. Iqbal, S. Rack, and L. D. Riek, "Movement coordination in human-robot teams: A dynamical systems approach," *IEEE Transactions on Robotics*, 2016.
[8] T. Iqbal and L. D. Riek, "Detecting and Synthesizing Synchronous Joint Action in Human-Robot Teams," in *Proc. of the ACM International Conference on Multimodal Interaction (ICMI)*, 2015.
[9] ——, "Human coordination dynamics with heterogeneous robots in a team," in *Proc. of the ACM/IEEE International Conference on Human Robot Interaction (HRI), Pioneers Workshop*, 2016.