D Nonverbal Communication in Socially Assistive Human-Robot Interaction

Henny Admoni (Dept. of Computer Science, Yale University; henny.admoni@yale.edu)
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Socially assistive robots provide assistance to human users through interactions that are inherently social. This category includes robot tutors that provide students with personalized one-on-one lessons (Ramachandran, Litoiu, & Scassellati, 2016), robot therapy assistants that help mediate social interactions between children with ASD and adult therapists (Scassellati, Admoni, & Matarić, 2012), and robot coaches that motivate children to make healthy eating choices (Short et al., 2014).

To successfully provide social assistance, these robots must understand people's beliefs, goals, and intentions, as communicated in the course of natural human-robot interactions. Human communication is multimodal, with verbal channels (i.e., speech) and nonverbal channels (e.g., eye gaze and gestures). Recognizing, understanding, and reasoning about multimodal human communication is an artificial intelligence challenge.

This dissertation focuses on **enabling human-robot communication by building models for understanding human nonverbal behavior and generating robot nonverbal behavior in socially assistive domains.** It investigates how to computationally model eye gaze and other nonverbal behaviors so that these behaviors can be used by socially assistive robots to improve human-robot collaboration.

Developing effective nonverbal communication for robots engages a number of disciplines across AI, including machine learning, computer vision, robotics, and cognitive modeling. This dissertation applies techniques from all of these disciplines, providing a greater understanding of the computational and human requirements for human-robot communication.

To focus nonverbal communication models on the features that most strongly influence human-robot interactions, I first conducted a series of studies that draw out human responses to specific robot nonverbal behaviors. These laboratory-based studies investigate how robot eye gaze compares to human eye gaze in eliciting reflexive attention shifts from human viewers (Admoni, Bank, Tan, & Toneva, 2011); how different features of robot gaze behavior promote the perception of a robot's attention toward a viewer (Admoni, Hayes, Feil-Seifer, Ullman, & Scassellati, 2013); whether people use robot eye gaze to support verbal object references and how they resolve conflicts in this multimodal communication (Admoni, Datsikas, & Scassellati, 2014); and what is the role of eye gaze and gesture in guiding behavior during human-robot collaboration (Admoni, Dragan, Srinivasa, & Scassellati, 2014).

Figure 1: Data from a human-human interaction was used to train a model for recognizing nonverbal communication.

Based on this understanding of nonverbal communication between people and robots, I develop two models for understanding and generating nonverbal behavior in human-robot interactions. The first model uses a data-driven approach (Admoni & Scassellati, 2014), trained on examples from human-human tutoring (Figure 1). This model can recognize the communicative intent of nonverbal behaviors, and suggest nonverbal behaviors to support a desired communication.

The second model takes a scene-based approach to generate nonverbal behavior for a

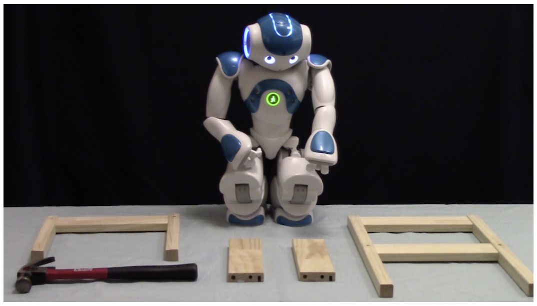

Figure 2: This dissertation includes a model for generating robot gaze and gestures for human-robot collaboration.

socially assistive robot (Figure 2) (Admoni, Weng, & Scassellati, 2016). This model is context independent and does not rely on a priori collection and annotation of human examples, as the first model does. Instead, it calculates how a user will perceive a visual scene from their own perspective based on cognitive psychology principles, and it then selects the best robot nonverbal behavior to direct the user's attention based on this predicted perception. The model can be flexibly applied to a range of scenes and a variety of robots with different physical capabilities. I show that this second model performs well in both a targeted evaluation and in a naturalistic human-robot collaborative interaction (Admoni, Weng, Hayes, & Scassellati, 2016).

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Henny Admoni is currently a postdoctoral fellow at the Robotics Institute at Carnegie Mellon University, where she works on assistive robotics and human-robot interaction with Siddhartha Srinivasa in the Personal Robotics Lab. Henny completed her PhD in Computer Science at Yale University with Professor Brian Scassellati. Henny develops intelligent robots that improve people's lives by providing assistance through social and physical interactions. Her scholarship has been recognized with awards such as the NSF Graduate Research Fellowship, the Google Anita Borg Memorial Scholarship, and the Palantir Women in Technology Scholarship.