Nonverbal Dialogues for Conflict Resolution: Exploring Hesitation Gestures in Human-Robot Conflict of Resource Scenarios

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1. INTRODUCTION

In this work, we investigate how *hesitation gestures* can be used to quickly resolve conflict of shared resources in human-robot collaboration contexts. Studies demonstrate that people, even while having different intentions and capabilities, use communication to interweave subplans and are able to collaborate with each other [1]. Likewise, in order for a human-robot pair to collaborate, it is essential for the two agents to communicate with each other and reach a decision about what should happen next [2]. This requires the agents to have appropriate means to communicate their internal states with each other as well as a mechanism to negotiate for a decision about what should happen next.

For example, people share spaces and objects with each other every day. This makes the occurrence of interpersonal conflicts regarding access to these shared resources inevitable. Nonetheless, people easily and seamlessly ask and answer the questions of 'who should yield?' and 'how should one yield?' by verbally and nonverbally communicating with each other. Similarly, when a human-robot pair shares a physical resource, the two agents may unintentionally attempt to access the resource at the same time.

Today's robots typically resort to preprogrammed responses, such as collision avoidance behaviours, when resource conflict occurs. Humans are treated as obstacles that, when detected at a close proximity, trigger a robot to abruptly stop and remain motionless until the 'obstacle' withdraws from its field of view. However, depending on the context and the agents' reasons for needing the resource, the outcome of the conflict may have functional, social, or even moral implications. Without a means for the agents to converse and reach a decision about the conflict of resource, one agent may be constantly deprived of the resource rendering the collaboration inefficient and yielding undesirable outcomes. We believe that when robots enter our homes and offices, how robots respond to these conflict scenarios will become a key roboethics concern. Our work aims to address this problem by implementing humanlike communication capabilities on a robot, such that a human-robot pair can communicate with each other to make context-appropriate decisions about the conflict.

This research is focused on developing a humanlike nonverbal communication mechanism for a robot. In particular, we are exploring whether hesitation gestures, i.e., nonverbal gestures commonly observed in human-human collaboration scenarios, can be implemented on a robot to elicit human-robot nonverbal dialogue about resource conflicts.

2. BACKGROUND

In order to develop a system that allows a human-robot pair to have a dialogue about and resolve a conflict of resource, a robot not only needs the ability to recognize and understand communicated contents from its user, but also needs the ability to convey its internal states to the user. Both verbal and nonverbal means of human-robot communication have been actively investigated within human-robot collaboration contexts. Studies demonstrate that the use of nonverbal gestures is an effective mode of communication between humans and robots [3, 4].

Based on these studies, we investigated whether we can utilize this phenomenon to communicate subtle gestures of hesitation during an *in situ* human-robot collaborative assembly context. Hesitations gestures are often observed in human-human resource conflict scenarios where two people reach for the same resource at the same time. These gestures manifest themselves as abrupt pauses or jerky motions of the limbs or the whole body when a conflict is encountered. There are two different types of hesitation gestures: retract (R) type and pause (P) type. Both types of hesitations occur in response to an imminent conflict of resource access [5]. However, use of P-type hesitations is sometimes bidirectional, enabling the two parties to engage in a nonverbal dialogue consisting of hesitations until a resolution of the conflict is reached. This is consistent with findings in psychology, which states that in order to resolve such resource conflicts people verbally and nonverbally communicate their intentions about the resource and negotiate a solution with each other [6].

3. METHOD

Our approach in studying hesitation gestures is to first observe how the gestures are manifested in human-human collaboration contexts. We then develop models of these gestures for implementation in robotic systems (Section 2.1). These models are used to generate reference trajectories of hesitation gestures for the robot. For example, in [5], we developed a controller for generating R-type hesitation gestures based on the characteristic trajectory profile observed in human hesitations. This is further outlined in Section 2.2. We plan to develop a control architecture that allows a robot to quickly respond to imminent resource conflicts using human-like designed hesitation gestures (Section 2.3). We aim to demonstrate the efficacy of the designed system by investigating a human-robot pair's ability to engage in nonverbal dialogue about resource conflicts using hesitation gestures.

3.1 Replicating Human Hesitations

In the first phase of our study, we conducted a human-human and human-robot interaction experiment to investigate whether a robot replicating the same wrist trajectories as that of human hesitation gestures can be perceived as being hesitant. We recorded a series of reach and retract motions of human subjects engaged in a human-human interaction task. In this task that involved one shared object, two people reached for the same object, and sometimes, by chance, at the same time. We reproduced this interaction as a human-robot interaction by replicating the subjects' Cartesian wrist trajectories with a 6-DOF robot. A total of 86 online participants watched video recordings of either the human-human or human-robot interactions, and identified where they saw either the subject or the robot hesitate. Findings from this study empirically validated that hesitation gestures can be communicative to human observers even when the gestures are embodied by an articulated robotic manipulator with a lower number of degrees of freedom than a human arm/hand. We also observed that people use P-type or R-type hesitation gestures, each of which expresses different level of persistent interest toward the shared resource.

3.2 Designing and Testing Hesitation Trajectories

With the human hesitation trajectory data collected from the abovementioned experiment, we extracted an acceleration profile common to R-type hesitation trajectories. To confirm that trajectories generated using this acceleration profile can also communicate hesitation to lay observers, we video recorded three versions of robot motions that follow the hesitation trajectory profile. These videos, along with videos of the same robot exhibiting nine other motions (12 videos in total), were shown to 58 online participants. These other motions include three versions of abrupt stops (typical of collision avoidance behaviour), collisions with a person reaching for the same object, and successful reaching motions without collision. Results from this study provide empirical evidence that people perceive robot motions with the derived hesitation acceleration profiles as hesitations ($F(2.49, 104.48) = 132.83, p < .001$).

To test the efficacy of the designed hesitation trajectories in a human-robot interaction context, we developed a real-time trajectory generator that can provide reference trajectories expressive of R-type hesitation gestures. Human participants performed a series of reaches while collaborating and sharing the same workspace with a 7-DOF robot (see Figure 1). In this task, participants reached for an object inside the shared bin, paired and sorted it with another item. When a conflict about access to the shared bin occurred, the robot either did not yield (i.e., continued to move towards the resource, resulting in a collision or a near collision situation), abruptly stopped, or exhibited R-type hesitation gestures. Results from this study indicate that a majority of the participants (79%) can accurately distinguish the robot's R-type hesitation gestures in situ from abrupt stopping behaviours.

3.3 Investigating the Efficacy of Hesitation-based Human-Robot Dialogue

In order to use hesitation gestures as a mechanism for human-robot nonverbal dialogue, we need to collect a larger vocabulary of hesitation gestures by similarly investigating P-type hesitation gestures. We are currently exploring characteristic features of P-type hesitation trajectories in order to develop an analogous real-time trajectory generator. Afterwards, we plan to develop a hybrid deliberative/reactive control architecture tailored to quickly detect and respond to human gestures using an appropriate type of hesitation gestures. Once the architecture has been developed, we plan to conduct an in situ HRI experiment to investigate the efficacy of nonverbal dialogues in resolving human-robot resource conflicts.

Figure 1. Experimental setup for our in-situ HRI study. A participant performs a task where there is a frequent need to access the resource shared with the robot.

4. DISCUSSION AND CONCLUSIONS

In this work, we outlined our approach to resolving resource conflicts between humans and robots sharing the same workspaces/objects. Results from our previous work suggest that designed hesitation gestures can be recognized by human observers in situ. We are optimistic that, analogous to their role in human-human interactions, hesitation gestures can help start and carry on an intuitive and natural nonverbal dialogue between humans and robots during collaboration scenarios. With the advent of robots entering our homes and offices, we believe a successful implementation of our completed system can help develop natural means of managing shared resources between humans and robots and help advance the field of human-robot collaboration.

5. ACKNOWLEDGMENTS

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