The Way You Move: The Effect of a Robot Surrogate Movement in Remote Collaboration

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ABSTRACT

In this paper, we discuss the role of the movement trajectory and velocity enabled by our tele-robotic system (ReMa) for remote collaboration on physical tasks. Our system reproduces changes in object orientation and position at a remote location using a humanoid robotic arm. However, even minor kinematics differences between robot and human arm can result in awkward or exaggerated robot movements. As a result, user communication with the robotic system can become less efficient, less fluent and more time intensive.

KEYWORDS

Robot surrogate; movement trajectory & velocity; remote collaboration

1 INTRODUCTION

Today, robotic systems assist humans in a wide range of tasks, including tasks that might be dangerous, that support household workload reduction, or that improve a person's communication and collaboration with others [1, 3, 5]. Because application domains are so varied, we need to design robots whose capabilities (e.g., kinematics behaviours) are tailored to their role. In practice, humans and robots have fundamentally different kinematics and speed capabilities which makes it challenging to use them as surrogates for humans [3, 5]. Following these differences Dragan et al. [2] defines "functional movements" as robot movements that are just planned to reach the goal position without any collisions. In their study, they examined a human-robot collocated scenario where the robot performed different motions to grasp a coloured cup. Participants determined the colour of the cup the robotic arm aimed for, following the robot's movement trajectory. Dragan et al. [2] found that functional motions were insufficient for human-robot collaborative tasks, because the intentions were difficult to predict and interpret.

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Figure 1: ReMa – Remote Manipulator: *While the end position is the same, the robot's movement trajectory to the goal position (right) does not match the human motion (left) due to the "wrist" joint limitation of the robot*

However, unless we design robots to exactly replicate human anatomy, we cannot truly replicate human motion, i.e. robots will ultimately follow different pathways and velocity dynamics when executing a movement. *How does the gap between human and robot motion, specifically trajectory and velocity, affect robot-mediated communication? How does this affect the design of novel robotic systems?*

2 ROBOT ACTS AS SURROGATE FOR HUMAN ACTIONS

We specifically developed the ReMa system to support two remote collaborators on physical object-focused tasks with the help of a Baxter robot [3]. One person worked collocated with the robot that held an identical object as a remote collaborator; the robot locally reproduced the orientation of the remote object to facilitate shared references between collaborators. Our study [3] examined the differences between video- and robot-mediated remote collaboration. Noticeable was that some participants expected the humanoid arm to act as a direct surrogate and thus match the movements of their remote collaborator's human arm.

In this paper, we re-analysed video data from two previous studies comparing ReMa to videoconferencing and looked at how participants reacted to the ReMa's elaborate or unnatural movements. We focus on how the 32 participants (16 pairs) responded to two aspects of non-human-like (functional) robot movements, *Trajectory* and *Velocity*.

Trajectory

The movement trajectory is an important part in human-robot communication and collaboration to understand and to improve the interaction with robots [2, 3, 4]. The participants clearly had difficulties; these functional movements interrupted their communication flow. For example, one collaborator in the study wanted to describe how the person controlling the robot should change the position/orientation of the object. “Can you just rotate it 90 degrees to the left” (P10). However, because of joint limitations, the robot rotates the object 270 degrees to the right (see Figure 1). As the robot starts to move the object in the opposite direction as instructed, the participant reacts: “No! Not in this direction…” (P9). Once the robot finished its movement s/he quickly realizes that the end-position is correct: “Ahh, forget it, it is right” (P9).

We observed the same issue when participants wanted to describe properties of an object that required a certain motion for bringing the object into positions that would allow a comprehensible view. For instance, one participant wanted to describe three attributes of an object by using a specific trajectory. S/he asks: “Can you just tilt it slowly till it is upside down” (P13). Her collaborator starts moving the object to the requested end-position, and the robot simultaneously moves its arm in a slightly different motion in order to re-adjust its joints so that it can reach the right end-position. Regarding this difference compared to the human movement she is confused and thinks that her partner misunderstood the instruction: “No…go back” (P13). These types of situations typically occurred at the beginning of the task and sometimes led to confusion until the group realized that they could not rely on the trajectory of the robot movement. Generally, after participant groups encountered such a situation and became aware of this system limitation, they no longer used motion trajectory for explanations.

Velocity

Due to the constant servo speed of the joints, all movements were executed with the same velocity and a consistent motion dynamic. This often created subtle inconsistencies between the participants’ movement and the robot’s, and affected the communication flow during the task. For instance, participants in the study wanted to slowly introduce themselves to the geometrical structure of the trophy object (see Figure 1), which was difficult to determine from a single perspective. P8 moved the trophy with a specific velocity, acceleration and jerk (change of acceleration with time) to show it to their remote collaborator. However, the robot executed the movement with its constant velocity and did not use the human acceleration and jerk, resulting in confusion and challenges to both participants. Participants also changed the velocity of their actions when they want to emphasize something, again with the robot failing to fully replicate these nuances. As a result, P7 complains about the constant motion velocity as they tried to explore the geometrical structure of the trophy: “Move it slower…it cannot follow you”. Subsequently, the group changed their strategy with P8 showing the “main” side of the trophy to P7, and verbally explaining how they should be adjusting their perspective. Eventually, both collaborators managed to explore the object simultaneously without the velocity shift between them. Additionally, tasks often required control of the velocity of an object to demonstrate or determine its behaviour in action (e.g. slow motion). Furthermore, a fixed velocity can potentially deter people from interacting with the robot, for example in case of a constantly fast approaching robot arm, moving in ways that can be interpreted as intimidating or threatening [4].

3 DISCUSSION

We observed that both aspects of object movement, *Trajectory* and *Velocity*, were important to facilitate interaction. When ReMa executed movements with incorrect or unexpected trajectories or velocities there were often subtle or even major affects on the remote collaborators. In spite of this, we observed that people could develop workarounds to support interaction with the derived overhead of increased total micro-task time (delay) needed to understand the robot action, due to the constant joint servo speed and the functional movements.

We conclude that *Trajectory* and *Velocity* are both important to consider for improving the communication flow and supporting the intelligibility of actions displayed by a humanoid robot. Designers of tele-robotic systems such as ReMa should consider our observations in order to facilitate natural, faster and more efficient remote collaboration. Our findings confirm previous work by Dragon et al. [2] in the context of remote human-human robot-mediated collaboration and highlight importance of movement trajectory and velocity.

There is still a long way to go until robots can act as a true surrogate for human action. In the interim, we should develop alternative ways to make these systems more effective. For example, Augmented Reality (AR) can visualize a remote collaborator’s object movement-trajectory while the robot manipulates the object to the correct end state in its own way. Alternately, robots can add a “naturality” variable for their search of various possible trajectories to move their arm to the goal position. Given a feedback mechanism, the robot could learn more natural movements over time and attempt to avoid purely functional motions.

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