Inferring the level of collaboration in object handover tasks: From one-to-one to one-to-many

Heramb Nemlekar and Zhi Li[1]

I. Introduction

The study of one-to-many handover is motivated by the scenario of (1) one autonomous robot serving many humans, and (2) human supervising multiple low-autonomy robots to serve their end users. The level of collaboration is about (1) whether the end user will perceive the autonomous robot or the entire human-robot teaming system to be collaborative or not, and (2) how to design such system to behave as a collaborative partner with all (or most) of the remote users.

Research in improving robot performance in handover tasks focuses on inferring human intent and planning robot motion such that it is efficient, intuitive, safe and comfortable for the human partner. Robot efficiency in handover tasks depends on the reaction time and accuracy of the robot response. Often, observations from human-human handover studies [1]–[3] are used to model expected human behaviour. Human posture, arm length and gaze can be used to predict a prior static estimate of the object transfer point [3], [4]. This static estimate can then be updated based on the observed human motion to promptly and accurately plan the robot reach-to-grasp motion [4].

Although predictive control leads to efficient and functional handovers, planning legible motions that clearly indicate the robot's intent lead to a more fluent collaboration [5]. Characteristics of collaborative fluency, such as the subjective and objective fluency metrics, observer and participant fluency perception, etc, help to evaluate the fluency of human-robot handovers [6]. Apart from fluency, factors like adaptability [7], compliance [8] and trust [9] also indicate the level of collaboration of the human or robot partner. For sequential tasks, adaptability can be measured based on the probability with which one partner adapts to the other partner's reward function [7]. Inferring the robot's reward function in a task also helps to build a human partner's trust in the robot's capabilities [10].

Although handovers have been studied for face-to-face, dynamic, repetitive and sequential task scenarios, the majority of the research deals with one-to-one handover tasks. A non-sequential one-to-many handover task would involve the additional problem of scheduling the robot's actions to cater to multiple users. In the case of mixed human-robot teams where a human leader has to allocate tasks to a human assistant and a robotic co-leader [11], task scheduling was done by minimizing the maximum amount of work assigned to an agent. Constraints for this problem considered lower bounds on time, number of tasks assigned to each agent and other temporal and spatial constraints of the task. However, the study only focused on how human satisfaction was affected by the level of robot autonomy and not the level of collaboration. In our proposed study, we aim to evaluate the aspects of a robot's performance that affect a human partner's perception of the robot's level of collaboration.

[1] Heramb Nemlekar and Zhi Li are with the Robotics Engineering Program, Worcester Polytechnic Institute, Worcester, MA 01609, USA {hsnemlekar, zli11}@wpi.edu

II. One-to-One Object Handover

To determine the factors that indicate the level of collaboration of a partner in an object handover task, we conducted a one-to-one human-human handover experiment.

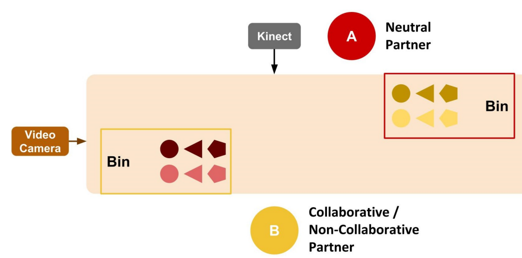

Fig. 1. Experiment setup for Pilot Study

As shown in Fig. 1, the subjects A and B were asked to stand on opposite sides of a table. 6 objects with different affordances were placed in each of the bins on either side of the table. The subjects were asked to collaborate in moving all the red objects to the red bin and yellow objects to the yellow bin. They were only allowed to handle one object at a time. A trial was considered complete when all the objects were in their respective bins.

The study comprised of 2 trials. In one trial, Subject B was asked to be **Collaborative** i.e. *be helpful to their partner*. In the other trial, Subject B was asked to be **Non-Collaborative** i.e. *offer minimum help to their partner*. Subject A was provided with no specific instruction and was unaware of Subject B's instruction. Subject A's behaviour was assumed to be neutral or collaborative. The order of collaborative and non-collaborative trials for all subjects was decided based on balanced latin square.

Subject B's movements were tracked through a Kinect sensor using the NI Mate motion capture system. The skeleton data was used to calculate the **object transfer point** and the **orientation** of the subject's body and head. A video camera on the side of the table captured the task scene. The video data was used used to record **verbal communication**, **object affordance**, the **timing of actions** and **total time**. At the end of the study both the subjects answered a questionnaire: