Investigating Human-Robot Handover Release Behaviors
Zhao Han, Holly Yanco
UMass Lowell Human-Robot Interaction Lab

Introduction
Most human-robot handovers focus on how to approach human receivers and notify the readiness, few have investigated the effects of difference release behaviors of objects.

The whole handover process consists of three phases: the approach phase, the signal phase, and the transfer phase. Failures during the transfer phase have serious consequences:

- Early releases lead to dropped and broken objects.
- Not releasing while human receivers desired to takes the object breaks handover fluency and makes human receivers have bad handover experience.

To increase handover fluency and improve handover experience, we developed different manners for robots to release objects during a human-robot handover and plan to conduct a user study to investigate the effects of different types of release behaviors:

- **Rigid release policy**: The robot first fully extends its arm and, only when reached, detect pull and release the object in hand.
- **Passive release policy**: The robot attempts to extend its arm fully and detect pull along the way, and release the object accordingly. A pull is detected if the exerted force is over a pre-defined threshold during a certain time interval.
- **Proactive release policy**: The robot attempts to extend its arm fully and actively detect a force change pattern corresponding to human grasp effort along the way, and release the object early.

Experiment Design

**Robot Platform**: A Baxter humanoid robot built by Rethink robotics is used in this experiment. Baxter is equipped with two 2-finger grippers and each gripper is equipped with a force sensor that outputs values ranging from 0 to 100 but is not available through their API. We attached a square, thin Force Sensing Resistor with an active sensor area of 12.7mm to the right gripper for grasp effort detection.

**Handover Design**: Baxter will hand over the cylinder, shown in Fig. 1, and release it according to the three policies. When released, Baxter retracts its arm.

- **Appropriate Distance**: The robot is placed approximately one meter away from participants, based on previous human-human handover studies on how a robot giver should approach receivers [1].
- **Facial Expression**: We used the facial expression designed by Fitter et al. [2] with modifications by adding eyelids movement to convey the handover task status and keep participants engaged.
- **Gazing Behavior**: Baxter turns its head and moves its eyeball to keep looking at the cylinder during the whole handover process to avoid shifting the human receiver’s attention, which negatively affects the handover efficiency [4].
- **Object Configuration**: Baxter’s right arm and gripper are used, suggested by [3]. The robot grasps the top part of the object, making the bottom of the cylinder towards participants around 10 cm so that the orientation of the object will not affect participants’ feeling on how easy it is to take the object, inspired by the studies of human preference of object configuration [6].
- **Human-Like Arm Movement**: Because the trajectory generated from the built-in inverse kinematics (IK) solver service always approaches objects from above, like an excavator, we used the moveit! framework and specified the orientation of the gripper so that Baxter approaches the object and participants in a human-like manner.
- **Full Arm Extension**: The arm of the robot is also as extended as possible to better signal the readiness of transferring the object [6].

This study has been submitted to the Institutional Review Board (IRB) and we expect the proactive release improve both overall experience and handover efficiency.

Release Policy Implementation

In the **rigid release policy**, the robot is programmed such that force detection only starts when the specified trajectory is completely executed. In the implementation, the program receives a force value message every 256 ms, which is the default rate provided by the hardware interface. We tested the handover force change and set its corresponding voltage ratio release threshold to 0.03 to avoid accident drops caused by arm movement and unstable stoppage.

The only difference between the **passive release policy** and the rigid release policy is that the force detection in the passive starts when the robot gripped the object firmly. This is implemented by empirically observing and setting an offset to the distance at which the firm status is reached after the grasp.

In the **proactive release policy**, the force detection starts at the same time and distance as in the passive release policy; however, it receives a message every 1 ms so that we can look for the pattern presented during a human grasp effort. Shown in Fig. 3, we observed the force data stream and found a decreasing pattern during different kinds of grasp attempt. In the implementation, we settled on accumulating streams of 40 windows of 180 force data. All windows are smoothed by calculating the average of each window of data. To determine whether to release, the program checks if 35% of the average values are decreasing.

References