Introduction

- Mobile robot has the potential to assist people in various domains, including applications in medicine, military, recreation and industry. We are particularly interested in robots that help people carry loads and follow people around in places like shopping malls.
- A challenge is that, these environments are usually highly dynamic and have many moving obstacles. The robot will inevitably get stuck, or move to a location deemed undesirable.
- We designed a “virtual tether” that enables bidirectional communication between human and the follower robot. We conducted experiments to evaluate the performance of the system.

Tether System Design

The Robot Follower

- We used Turtlebot 2 with Microsoft Kinect as the robot follower.
- Human’s relative position is extracted from tracking the color of the user’s clothes, combined with depth sensing.
- The following algorithm is given by:
  \[
  v = k_{p,v}(y - y_d) - k_{d,v}\dot{y} \\
  \omega = -k_{p,\omega}\dot{x} - k_{d,\omega}\dot{\omega}
  \]

Tether System Hardware

The tether system consists of two parts: a haptic interface to convey information from robot to human, and an command interface to convey information from human to robot.

- The haptic interface is capable of rendering 4 different directions with asymmetric vibrations.
- The command interface uses a 9-axis IMU to sense the orientation of user’s hand, and can be used to teleoperate the robot follower.

Experiment and Results

Study I: Multi-Tasking

In Study I, we focus on scenarios where the users are engaged in multiple tasks and mentally distracted from the robot follower.

Study II: Navigation

In Study II, we investigated how people would use the tether to teleoperate and help the robot to avoid obstacles.

Analysis and Results

- Study I: We compared the number of times that the robot became stuck, the duration of the stuck states, and the user’s performance on their tasks.
- Study II: We investigated learning effect by looking at the trial time vs. trial number. We also studied how users chose between using the tether and taking a detour.

Conclusions and Future Work

- We showed that the tether can increase users’ awareness of the robot follower’s status and lower their mental effort, thus helping the users perform better on other tasks.
- We demonstrated that the users can successfully use the command interface to help the robot follower navigate in a cluttered environment that it could not autonomously.

As next steps, we plan to:

1. Further explore the use of directional haptic information. We are interested in increasing the number of directions that the haptic interface can display, and using them to convey richer information.
2. Develop methods that allow users to use natural gestures to communicate high-level intentions with the robot follower.