Towards Social-Acceptability of Mobile Robots through Motion Communication Cues

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I. Introduction

There is a rapid rise in the presence of mobile robots in shared human spaces - the International Federation of Robots predicts a 323% increase in the use of mobile robots for logistics by 2021 [1]. The delivery industry is a rapidly-developing space for logistics robots - McKinsey and Company forecasts that robots will be used for 80% of last-mile deliveries in the future [2].

In addition to their economic benefits, mobile robots can provide a welcome addition to the pedestrian landscape, initially as a novelty, but in the future as a helpful and contributing member of the travelling public, providing delivery services, wayfinding, and security. They can, however, also be confronting and cause discomfort when moving through shared human spaces.

Walking on the sidewalk is natural and comfortable for most pedestrians. We inherently engage in joint collision avoidance with others in public spaces, based on a variety of subtle body language cues and well-developed models of how other people move [3]. Understanding how others move is a key component to feeling comfortable on the sidewalk. People do not, however, have a good understanding of how robots move, which can lead to discomfort and perceived lack of safety when the two share a space.

Most commercial robots deployed for last-mile delivery communicate with end users, but not pedestrians. Only one such robot, Postmates' Serve [4], uses flashing lights as turning signals to communicate its motion to pedestrians. While Serve does use a motion communication cue, this research space is underdeveloped and questions remain as to what type of communication cue is effective in this context.

Both Watanabe et al. [5] and Chadalavada et al. [6] developed light projection systems to project a mobile robot's path into a shared human space. Both studies found light projection to be effective at increasing the comfort of research participants when compared to no communication cue. May et al. [7] compared two communication cues: anthropomorphic gaze and car-like flashing lights. They found the flashing lights cue to be more effective than gaze. The single motion communication cue currently deployed on a last-mile delivery robot - flashing lights - has only been compared to a gaze cue. This proposed work will compare a path projection cue to a flashing lights cue as a next step towards better understanding which cues will provide more effective and comfortable communication to pedestrians.

Figure 1: Flashing lights cue

II. Experiment Apparatus

In our ongoing experimental work, we use mixed-reality as both a prototyping and experimentation tool. We have prototyped two communication cues (flashing lights and path projection) in the Unity game engine and overlay them as holograms on the mobile platform with the Microsoft HoloLens mixed-reality headset. Figure 1 shows the flashing lights cue (circled) projected onto the mobile robot, as seen through the HoloLens.

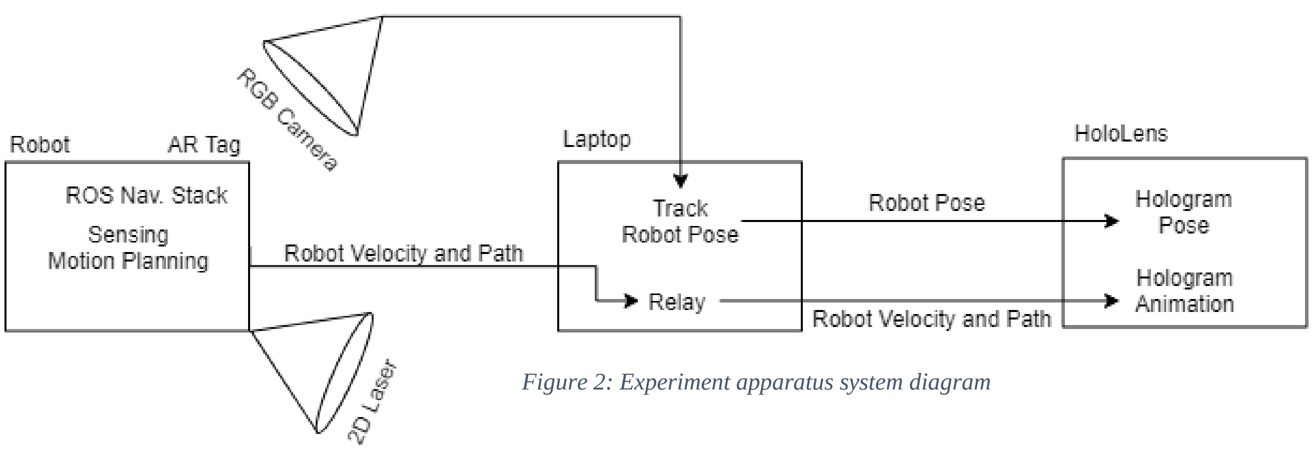

Figure 2: Experiment apparatus system diagram

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The flashing lights cue is modelled after the approach shown to be effective by May et al. (2 Hz, orange). The path projection cue, which is under development, is modelled after Watanabe et al.'s successful design.

Figure 2 shows the experiment setup. The mobile robot (Adept PowerBot, differential drive) uses the ROS Navigation Stack and a 2D laser scanner to sense, plan, and move through the experiment workspace. We take the ROS Navigation Stack as a standard in mobile robotics prototyping, which will help us generalize our results to other robots running the same software. A laptop base-station uses an overhead RGB camera to track the robot's pose, which it relays, along with the velocity and local path, to the HoloLens. We use the velocity and path data to animate the flashing lights and path projection holograms respectively, and the pose data to project the holograms onto the robot.

III. Experiment Design

We will use a one-way MANOVA to analyze the effect of communication cue (flashing lights, path projection, none) on both social-acceptability and trajectory smoothness. We measure social-acceptability with four 5-point Likert-scale questions, which assess cue clarity and obtrusiveness, and participant confidence and comfort. We take the HoloLens' velocity as the walking direction of the participant, and the variance therein as the participant's trajectory smoothness. These social-acceptability questions are adapted from [5-7], and the trajectory smoothness measure comes from Watanabe et al.

Figure 3 shows the two walking tasks participants must complete with the robot in a shared space.

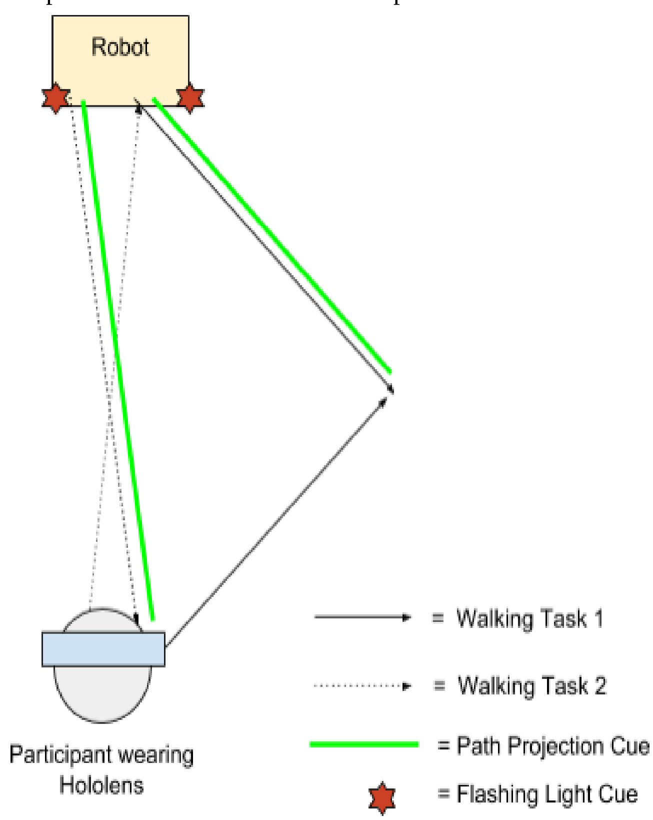

Figure 3: Experiment tasks

After a familiarization phase, participants perform the walking tasks in Figure 3 with each cue, in a counterbalanced order. The perpendicular pattern (task 1) simulates a pedestrian and the robot turning a corner in opposite directions; the low-angle pattern (task 2) simulates the robot passing a pedestrian on the sidewalk We treat each task as a separate test.

For both tests, we predict a significant main effect of communication cue on both social-acceptability and trajectory smoothness, with no significant interaction effects between the two dependent variables. We do not hypothesize which cue will be more effective, as this is an exploratory study. Preliminary results will be presented at the time of the workshop.

IV. Contributions and Future Work

Our work will compare the path projection and flashing lights communication cues on a mobile robot for the first time, for the purpose of increasing human understanding of robot movement. While we intend to elucidate which communication cue is more effective, the mixed-reality apparatus limits the external validity of that claim. A subsequent field study will physically prototype the more effective cue from this work and evaluate the physical prototype in a shared space with multiple pedestrians.

Acknowledgment

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