Shared-control in Wheelchairs – Building Interaction Bridges

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ABSTRACT

Navigating through human crowds is a challenging task for autonomous and semi-autonomous vehicles. In this extended abstract, we propose the exploration of two interaction bridges: 1) between the navigator and user; 2) between the wheelchair (and user) and the public/pedestrians. By further exploring these two bridges we argue that interaction between the user and the wheelchair can become more intuitive, utilizing more efficient feedback strategies. Our preliminary analysis in shared-control wheelchairs could potentially be extended to shared-control robots and semi-autonomous vehicles.

ACM CLASSIFICATION KEYWORDS

• **Human-centered computing** → Social navigation; Human-Computer Interaction (HCI)

KEYWORDS

Shared-control; Wheelchair; Trajectory prediction; Feedback

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(a)

(b)

(c)

Figure 1—Commercially available interfaces
(From top to bottom: Joystick, Head-array switch, Sip-puff switch)

INTRODUCTION

Designing autonomous and semi-autonomous vehicle navigation strategies in pedestrian spaces such that the vehicle behaves in a socially compliant manner is a challenging task. In a crowded environment, for example, the algorithms designed to avoid collision may not work, and the resulting uncertainty may result in the vehicle "freezing" [11]. To deal with this issue, it is essential to predict pedestrian trajectories. Since people normally interact or cooperate with other people as they move through space it is essential that this interaction is also incorporated into any model.
The area of robot navigation has a growing body of research. However, much of the research focuses on autonomous vehicles. Although some major breakthroughs have been made in this area, there are still some cases where autonomous driving may fail. Under such cases, shared control could be a promising alternative. Instead of providing full autonomy, shared control negotiates between the user and navigator in order to provide a safe and comfortable driving experience.
One useful application of shared control is smart wheelchairs which use sensors to perceive the environment and a controller for trajectories planning. Recently, an increased number of prototypes have been developed globally which look at shared-control interfaces for electric wheelchairs [8, 14]. Some studies have investigated the use of novel feedback systems between the wheelchair and the user [4, 9,16]. However these studies are few and despite a growing body of literature on shared control of wheelchairs, few studies have approached the subject from a user-centred design perspective [5]. Furthermore, many of the systems created build on the technical competencies within a laboratory or research group, and as these can have a focus on haptics or vision for example, a bias towards this area of research expertise can emerge.
In this position paper we investigated a specific shared control wheelchair framework and make an analogy to semi-autonomous vehicles more generally. We argue the need for a user-centred design approach which incorporates multimodal feedback methods and results in socially compliant navigation. We propose the exploration of two interaction bridges: 1) between the navigator and user; 2) between the wheelchair (and user) and the public/pedestrians. We put forward some initial suggestions for design in this space, in the hope of providing insights into semi-autonomous vehicle navigation and user's awareness gaining during such process.

BACKGROUND

The needs of communication between pedestrians and vehicles with different levels of autonomy has been explored by [6]. They argue that for semi-autonomous vehicles, detecting pedestrians is not enough, and additional information such as pedestrian intention which could be influenced by the vehicle should be incorporated. Inspired by this argument, we propose a new shared control paradigm where such interaction is incorporated into planner's navigation algorithms.

Vehicle Navigation & Pedestrian trajectory prediction

Early research in this domain has used attractive and repulsive force to model interaction between humans while ensuring collision avoidance. However, this model did not capture possible cooperation which may occur in dense crowds where humans share the space with vehicles.

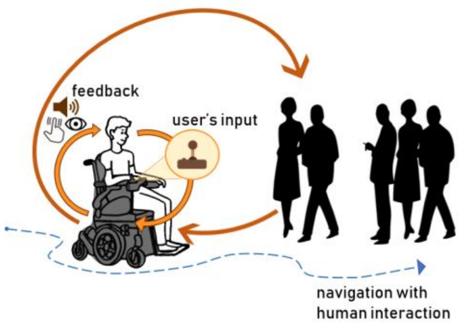

Figure 2—Proposed two interaction bridges in shared-control wheelchair navigation

Recent work that has addressed this problem include [11], which proposed an Interacting Gaussian Process that models the joint distribution of trajectories of all agents in the crowd using Gaussian processes. Interaction is modelled based on proximity with hand-crafted features, however, other potentially important features such as direction and velocity are ignored. These issues are addressed in data-driven methods proposed in [1, 2, 3, 12]. Due to its proven success in sequence prediction tasks, Recurrent Neural Network (RNN) has received much attention in human trajectory prediction. As a RNN does not capture dependencies between multiple correlated sequences, a social pooling layer which connect individual Long Short-Term Memory so as to automatically learn typical interactions in proposed in [1]. Similarly, an attention module is introduced in [12] to learn the importance of surrounding agents rather than considering only spatially local agents. Inspired by [12], Chen et al. adopted a deep reinforcement learning framework with a social attentive pooling module to encode crowd cooperative behaviour [3]. In addition, a small body of work is conducted in the social-scene area where scene context and social interaction are modelled simultaneously [7, 15]. This area of research hypothesizes that a similar walking pattern can be found in similar scene layout, thus understanding scene information would be beneficial for human trajectory prediction.

These algorithms have demonstrated their advantage in human trajectory prediction in an autonomous setting. We argue that if such algorithms were applied in a shared-control context, semi-autonomous wheelchairs could potentially navigate in crowds in a socially complaint way.

User-wheelchair Interaction: Interface and feedback for shared control

In terms of human robot interaction, the bridge between the user and the wheelchair is built through a driving interface. Commercially available interfaces (see **Figure 1**) are commonly available but only offer one-way interaction, and do not provide any feedback. Prototype multimodal interfaces (e.g.[8]) have been developed, which allow the user to control the wheelchair through multiple types of inputs, namely voice, facial expressions, head movement, keyboard and joystick. However, feedback has only been tested in limited scenarios. Current feedback strategies can be divided into two categories: single and multiple sensory channels. Wang et al. tested force feedback via a haptic joystick in a simulated environment. The study showed that completely blocking wheelchair movement in the user's chosen direction was unacceptable to users [14]. This issue was addressed by [4] and [9], who generated active and passive force feedback simulating a spring effect as the user moved towards an obstacle. Experimental results suggested that haptic feedback reduced joystick input amplitude. However, it is pointed out by [14] that sensory processing capability declines with aging, thus single channel feedback may not be sufficient to cover all types of users. Inspired by this argument, [5] proposed providing feedback in a more intuitive way through the combination of a user centric wearable skin stretch device and

Possible Topics to Discuss in the Workshop

We propose two possible topics to be discussed:

- What role can smart wheelchair navigation play in advancing the state of the art in semi-autonomous vehicle interaction knowledge?
- How should novel interfaces be tested? How do we safely move beyond lab-based studies?

haptic joystick. In addition to haptic feedback, [14] tested multimodal feedback strategy which combines haptic, visual and auditory. Visual feedback was implemented using 8 indicator lights around a joystick to show the allowed driving direction. The multimodal feedback was reported to be useful, but it was suggested that a more intuitive visual indication could be designed. [16] proposed visual feedback through a novel augmented reality device for wheelchair navigation. Results suggested the potential for visual feedback using AR, although the type of visualization needs to be carefully considered. Previous findings suggest that in order to design a user-centric smart wheelchair, single channel feedback may not be enough.

FUTURE WORK

We aim to design a user-centric smart wheelchair and propose two interaction bridges as depicted in **Figure 2.** Future work towards building the user-wheelchair bridge would build on the initial work to incorporate multimodal feedback (e.g. haptic and visual). Such feedback has proven more beneficial in terms of performance and decreased mental load [13] and has been shown to be better than only visual in a meta-analysis [10]. Different visual cues and modes of presentation could be explored to provide more effective and intuitive feedback. For example, by using LED projections in front of the wheelchair to show trajectory. Deviation of user's input and the final selected command could be provided through haptics. Therefore, information specific to the user can be fed back privately and both user and pedestrian can be informed of mutually beneficial information.

In terms of the bridge between the wheelchair system and pedestrians, human robot interaction aware trajectory prediction algorithms which have only been tested in autonomous robots could be combined with shared control and applied in a smart wheelchair setting. Hopefully, this would allow a shared-controlled wheelchair to navigate in a socially compliant manner in a crowded environment.

CONCLUSION

This paper explored the interaction among user, wheelchair and pedestrians. A two bridge interaction paradigm is proposed and specifically addressed in shared control wheelchairs. With the aim to facilitate interaction between the user and the wheelchair, more intuitive and efficient feedback strategies should be encouraged. Regarding the shared-control navigation, interaction between the wheelchair and the pedestrian should be explored and combined with user input to allow wheelchair to navigate in a crowded environment.

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