Understanding mental models in robot navigation

A shared-controlled wheelchair case study

Bingqing Zhang
Computer Science
University College London
United Kingdom
bingqing.zhang.18@ucl.ac.uk

Catherine Holloway
UCL Interaction Centre
University College London
United Kingdom
c.holloway@ucl.ac.uk

Tom Carlson
Aspire CREATe
University College London
United Kingdom
t.carlson@ucl.ac.uk

ABSTRACT

In human-robot interaction, the user's mental model of the robot plays a significant role in the effectiveness of the interaction. In the shared-controlled wheelchair navigation task, the interaction happens between the wheelchair and its user, as well as its surrounding pedestrians. Thus, understanding pedestrians' mental models is essential for safe and social navigation.

CCS CONCEPTS

• Human-centered computing~Human computer interaction (HCI)

KEYWORDS

Shared-controlled wheelchair; Navigation

1 Introduction

Robots and humans increasingly interact in public places, where they achieve tasks collaboratively. For effective human-robot interaction, it is key to build and understand the user's mental model during the task. In this paper, we investigate a special HRI scenario where a wheelchair user drives a shared-controlled wheelchair to navigate in crowds.

A shared-controlled wheelchair is made of a standard electrical wheelchair and a collection of sensors (see Figure 1). Our wheelchair consists of four clusters of ultrasonic sensors, an RGB-D camera and one 2D Lidar (not shown). It has the ability to sense its environment and generate collision free actions. In this sense, we consider it as a robot.

Different from fully autonomous robots, a shared-controlled wheelchair consists of a human-in-the-loop control framework, which makes it a special case to study in terms of human-robot interaction. To achieve safe and social navigation, we proposed building two two-way interaction bridges [7]. The first bridge is between the wheelchair path planner and its user. In order to drive the wheelchair, the user has to express his or her driving intention through an interface and the path planner will generate collision free action by taking the user's intention into account. Although the wheelchair tends to follow its user's intention in most scenarios, they may differ when the user's command is considered dangerous, which could leave the user to be confused. To address this issue, recent studies have been exploring feedback using visual [6,8] and haptics [2,3] techniques, with the aim of providing wheelchair users with the mental model of wheelchair's intended action. However, it remains a challenge to provide efficient and intuitive feedback to the user.

Figure 1. Our smart wheelchair with a collection of sensors

On the other hand, when such a wheelchair is driven in crowds, it further interacts with its surrounding pedestrians. During these interactions, pedestrians must be and feel safe, and this necessitates the mutual understanding of movement between the two parties [7]. Recent researches address this issue by predicting pedestrian's future trajectory and thus achieve joint collision avoidance [1,4,5].

However, those methods are based on the assumption that pedestrians avoid any robots the same way as they do to a human, which may not be true. In addition, those works only focus on autonomous robots and leaving shared-control (especially with a user that can be seen) to be explored.

In this paper, we investigate the validity of such assumption through a preliminary study, trying to understand whether pedestrians hold different mental model towards two robot platforms: A shared-controlled wheelchair (Figure1, with a driver) and a humanoid robot (Pepper), and how this affects their navigation behaviour.

2 Preliminary study

We designed a controlled gate-crossing task where 28 participants (15 females and 13 males, M=33 years old, SD=8.8 years, none of them has a mobility impairment and none has participated in a similar task before) were involved. Ethics have been approved and consent from participants have been obtained.

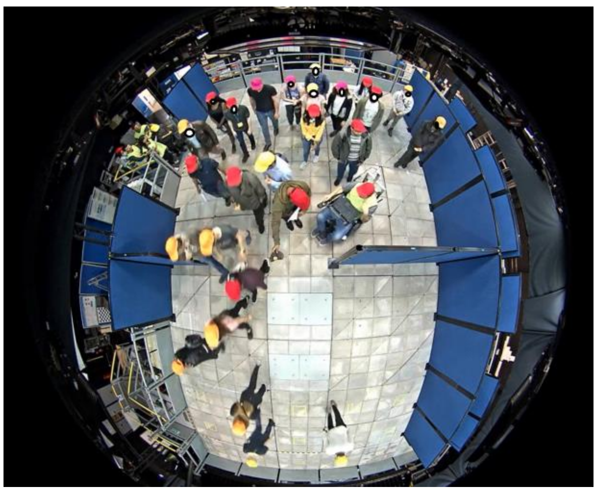

Figure 2. A pedestrian is using gesture to communicate his intention to let the wheelchair pass

In order to simulate crowds, all participants were instructed to walk at the same time from side to the other side of the platform, by crossing a 2m wide gate. Three main scenarios were designed where participants walk with a shared-controlled wheelchair, a Pepper (controlled remotely) or without any robot. Each scenario was repeated 10 times and participants' initial positions were randomized to maximize human-robot interaction and avoid potential bias towards certain participant's walking behavior. After each trial, participants were asked to complete a short survey asking them to reflect their perception and actions. The experiment was recorded by an overhead CCTV and trajectories were extracted for analysis. Our initial analysis of trajectory data indicates that pedestrians' avoidance behaviour varies across two robot platforms. For example, during gate crossing, pedestrians tend to adapt their trajectory by giving way to the wheelchair but overtaking Pepper. This difference in action could be explained by the fact that participants hold different mental models towards the wheelchair and the humanoid robot. This is further supported by the survey result that 84% of participants do not consider the wheelchair as a robot despite its exposed sensors which makes its appearance different from a standard wheelchair, while all participants recognize Pepper as a robot. A potential explanation could be that a human's mental model towards an object is built on their past experience. As a result, when they saw the shared-controlled wheelchair, it matched more with the image of a normal wheelchair thus triggering their cognition of this as a mobility tool for wheelchair users instead of a robot, which further affect their action.

In addition, the fact that a visible human user was controlling the wheelchair further affect their cognition. The survey result shows that 11% of participants claimed that they communicated their walking intention with the wheelchair driver by using gestures and eye contact (Figure2), while these numbers are only 0% and 4% in the Pepper case. This indicates that pedestrians tend to communicate their intention with the human (wheelchair user) as they naturally do in daily life. This poses a unique challenge in the shared-controlled setting, as the understanding of pedestrians' communicated intention may differ between the user and the path planner, which could lead to the movement that was unexpected by the pedestrians. This issue could partly be addressed by communicating the wheelchair's planned action to its surrounding pedestrians, which has been studied for the autonomous vehicle [1]. However, as the user and the wheelchair could communicate their intention to the pedestrians at the same time and may conflict with each other, it should be dealt with care. In terms of navigation strategy, the requirement of understanding pedestrians' intention for the path planner is highly associated with its user's capability and the nature of the environment. For a highly capable wheelchair user, it would be intuitive to let the user taking care of the social navigation part, while the path planner only deals with low-level collision avoidance.

3 Future Work

This paper presents our preliminary study in human-shared controlled wheelchair interaction, with the focus on understanding pedestrians' mental model and its effects on the joint navigation task.

In the future, we would like to investigate whether pedestrians could perceive the wheelchair's different intelligence levels and how it relates to their walking behaviour. In addition, we would like to explore wheelchair user's perception of shared control and investigate the effect of feedbacks (e.g. Visual signals indicating the wheelchairs intended trajectory) in these interactions., aiming to provide navigation assistance in a more intuitive and explainable way.

REFERENCES

[1]. David Ellis, Eric Sommerlade, and Ian Reid. 2009. Modelling pedestrian trajectory patterns with Gaussian processes. *2009 IEEE 12th International Conference on Computer Vision Workshops, ICCV Workshops*, IEEE, 1229–1234.

[2]. Mohammed-Amine Hadj-Abdelkader, Guy Bourhis, and Brahim Cherki. 2012. Haptic Feedback Control of a Smart Wheelchair. *Applied Bionics and Biomechanics* 9, 2: 181–192.

[3]. Namita Anil Kumar, Han Ul Yoon, and Pilwon Hur. 2017. A user-centric feedback device for powered wheelchairs comprising a wearable skin stretch device and a haptic joystick. *2017 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)*, IEEE, 1–2.

[4]. Mingming Li, Rui Jiang, Shuzhi Sam Ge, and Tong Heng Lee. 2018. Role playing learning for socially concomitant mobile robot navigation. *CAAI Transactions on Intelligence Technology* 3, 1: 49–58.

[5]. S Pellegrini, A Ess, K Schindler, and L van Gool. 2009. You'll never walk alone: Modeling social behavior for multi-target tracking. *2009 IEEE 12th International Conference on Computer Vision*, IEEE, 261–268.

[6]. Rosalie H. Wang, Alex Mihailidis, Tilak Dutta, and Geoff R. Fernie. 2011. Usability testing of multimodal feedback interface and simulated collision-avoidance power wheelchair for long-term-care home residents with cognitive impairments. *The Journal of Rehabilitation Research and Development* 48, 7: 801.

[7]. Bingqing Zhang, Roxana Ramirez Herrera, Catherine Holloway, and Tom Carlson. Shared-control in Wheelchairs – Building Interaction Bridges. 6.

[8]. Mark Zolotas, Joshua Elsdon, and Yiannis Demiris. 2018. Head-Mounted Augmented Reality for Explainable Robotic Wheelchair Assistance. *2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, IEEE, 1823–1829.

[9].Karthik Mahadevan, Sowmya Somanath, and Ehud Sharlin. 2018. Communicating Awareness and Intent in Autonomous Vehicle-Pedestrian Interaction. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, ACM Press, 1–12.