Experiencing Social Robots for Traffic Guidance using Virtual Reality Videos

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Abstract

Integrating autonomous vehicles and smart infrastructure into urban traffic systems is a crucial component for the development of future cities. Therefore, effective public communication and early citizen involvement is essential to align expectations with the capabilities of novel technology. We propose to use point of view 360-degree videos in Virtual Reality to present potential technologies in early stages to stakeholders, accelerate design processes and to measure physiological responses. We demonstrate our proposed method by the use case of social robots using V2X communication and arm gestures for pedestrian traffic guidance at unsignalized intersections. Initial video recordings with the robot in traffic in a Wizard of Oz setting showed curiosity among pedestrians about the robot's use case.

CCS Concepts

• **Human-centered computing** → **HCI design and evaluation methods**; **Virtual reality**.

Keywords

Social Robots, V2X, Virtual Reality, Simulation, Traffic, Vulnerable Road User

1 Introduction

Cities evolve towards integrating autonomous vehicles (AV) and smart infrastructure into daily traffic. Presenting new technologies to citizens before their deployment remains a major challenge [4]. Surveys are a common method for citizen involvement, although expectations of new technologies can be different [1, 6]. Once a technology is deployed, there are often further research questions to be uncovered and technology acceptance in the field can become a concern. For example, delivery robots in daily traffic are proposed to reduce delivery costs [12], but raised concerns among pedestrians due to blocking sideways once they were tested in the field [20].

We propose to use 360-degree videos to demonstrate the experience of new technologies in early stages using Virtual Reality (VR) and additional measurements. Efforts of creating compelling virtual environments can be reduced to simple one day video recordings. The use case we present are social robots for traffic guidance of pedestrians intending to cross a lively street at unsignalized intersections where heavy traffic is expected only at certain times of the day. Enabled by vehicle-to-everything (V2X) communication, robots will be even aware of hidden vehicles and capable of alerting pedestrians of approaching cars and emergency vehicles. Based on V2X traffic data, the robot can then decide and autonomously move between different high-traffic locations, potentially improving safety in a similar way to school crossing guards. In the VR video environment, additional measurements such as head movement and heart rate variability can be used to evaluate the targeted solution. Along with subsequent assessment of workload, perceived safety as well as interviews, VR videos can potentially accelerate design processes.

2 Related Work

Robots are increasingly considered by researchers to be integrated into traffic management and safety roles. For instance, police robots were proposed for manual traffic control and emergency situations, using specific gestures for guidance [7, 17]. Similarly, simulated traffic environments have been used to evaluate the performance of humanoid robots in controlling traffic [5, 13]. Traffic safety moderator robots for road workers could potentially enhance safety, but require further efforts to be accepted [11]. These innovations are paralleled by guide-dog robots, which assist vision-impaired pedestrians by detecting surrounding traffic [3, 8, 18, 19]. Discussions around the involved ethical issues in particular of crowd control robots suggest that the benefits outweigh the concerns [16]. Moreover, in the context of communication between AVs and pedestrians, the use of robotic objects in the passenger cabin has been explored to signal whether it is safe to cross [10].

The above-mentioned related works mostly use simulations and first prototypes to showcase their proposed technology and its usefulness. However, vision videos have been identified in the literature as an appropriate method to communicate new technologies with stakeholders in early stages [15]. These videos are typically utilized

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Figure 1: Gesture set of the social traffic robot. In A the robot is in the initial state. In B the robot blocks the path by spreading the arms. In C the robot moves slightly to the side and indicates to give way by opening the right hand.

to illustrate a desired future technology, inspire stakeholders, and communicate complex concepts more effectively. Extending this method to a more realistic experience by immersing the stakeholders virtually into a real traffic environment can potentially also uncover factors related to perceived safety, stress, and involved workload in relation to a common crossing scenario.

3 System

Our intended system can be divided into the main components social robot and virtual video. While the robot is only used for the video shoots, the recorded 360-degree VR videos are used for the later analysis of the system.

3.1 Social Robot

We selected the humanoid robot ARI by PAL robotics [1] for our video. Standing at 165 cm tall ARI features a sleek, modern design with expressive facial animations and a touch screen interface on its chest for intuitive interaction and warnings related to traffic events. Equipped with a variety of sensors, including 3D cameras, LIDAR, and microphones, ARI can navigate spaces autonomously, recognize faces and objects, and engage in meaningful conversations. With its friendly appearance and cutting-edge technology, ARI is well-suited for our analysis. Alternatively, virtual companions could be embedded in the videos instead of physical robots but could add confounding related to the virtual-to-reality gap in the presented video.

Inspired by [17], we developed a first set of gestures for the video shoot. Figure 1 shows the gesture set of the robot. In A, the robot is in its initial state sensing the environment and communicating measurements with the V2X traffic system. In case the smart environment indicates an approaching car or emergency vehicle and the robot senses pedestrians intending to cross the road, the robot initiates position B. By spreading the arms it blocks the path to make the pedestrians aware of the approaching traffic. When all vehicles have passed and it is safe to cross, it initiates position C. Therefore, the robot slightly moves to the side while lowering its arms and providing a cue with the right hand to indicate that it is safe to cross the road. Once all pedestrians have passed the robot, it moves back to position A.

[1] https://pal-robotics.com/robots/ari/

3.2 Virtual Reality Video

As the intention is to replay videos from the point of view of a pedestrian intending to cross a road in virtual reality, we selected the *Insta360 ONE RS 1-inch 360 Edition* camera which provides an image stabilization and a high resolution. The VR headset *Meta Quest 3* was chosen because of its mobile use, making it easy to present the intended use cases to citizens and other stakeholders in different locations with minimal effort. For the videos, the recording person was holding the camera in 360-degree mode on a selfie stick at a height of about 175cm above the head. A second person was watching the traffic all the time and initiating robot commands over a wireless connection. A third experimenter standing on the other side of the road ensured the safety of the experiment and communicated via inconspicuous hand signs that it is safe to cross. In this way, V2X communication could be simulated in a Wizard of Oz fashion. The person holding the camera on the selfie stick was also able to overview the traffic, but had to make sure that the camera was held still during the recording. Once all vehicles have passed, ARI was put into position C, as shown in Figure 1, and the

person holding the camera crossed the road. The recordings were repeated several times and included trials without the robot as a baseline condition.

The videos were imported afterwards into the virtual environment using Insta360 Studio for the video conversion and Unity Software to create the virtual environment. The VR headset offers additional data collection capabilities for subsequent experiments. Beside timestamps of the current played video, 3D-rotations of the field of view can be later used for an examination of head movements during road crossings. Additionally, we implemented functionalities for collecting heart rate variability measurements as a psychological stress indicator [9] from a *Polar H10* chest strap. Optionally, a *Nordic Thingy:52* IoT device attached to the feet can be used to measure the walking behavior in the VR by encouraging the user to walk on the spot.

4 Qualitative Observations

For our video shoot, we selected an unsignalized intersection with higher traffic around lunch time near the cafeteria on the campus of the Karlsruhe Institute of Technology. From an initial exploration of potential intersections, we observed potential harms at this spot due to different crossing behaviors. During the recordings, we had several interactions with mostly students. In the conversations, people were curious about the robot, its use cases, and why it was placed here. People wanted to touch the robot and interact with it, e.g. by starting conversations or waving hands. One person even hugged the robot when ARI was spreading the arms, indicating further research is required on the gesture set. We also inquired about their impressions on this particular unsignalized intersection and people agreed that this intersection is rather disorganized with people crossing the road without paying much attention to the traffic. During our video shoot, people were taking pictures and watching our process. As people watching could potentially affect later analysis with users in the VR, videos were recorded several times to select the ones with less obtrusive watchers.

5 Conclusion

We proposed to use 360-degree videos for communicating novel technologies and measuring physiological responses. To exemplify our approach, we presented social robots as traffic guides. A first video shoot with the robot ARI was performed and showed a curiosity among pedestrians about the use of social robots in traffic. The robot's display was found to be too dark to see the information displayed in video recordings. While we had a physical robot in place, virtual companions could be embedded into the videos instead to reduce the curiosity of nearby pedestrians and to further accelerate the design process. However, while videos remove efforts related to creating compelling virtual environments and potentially contribute to an enhanced overall realism of the presented virtuality, they do not provide a full interaction loop based on the user's behavior. Moreover, motion sickness must be taken into account when using VR headsets [2]. The environment and walking speed can have an impact on the susceptibility to motion sickness, which can be countered by reducing the number of fast moving objects and limiting the time of VR use [14]. Nevertheless, videos are an easy and simple tool to communicate intended use cases in the early stages to engage citizens in the development and research process. Additional data collection using internal VR headset measurements such as head motion and body-worn health data, along with interviews and standardized questionnaires, can potentially provide nuanced insights into user experiences, physiological responses, and behavioral patterns during VR interactions.

Future research will involve user tests and data collection regarding perceived safety, stress and further variables of interest. This will be accompanied by a citizen involvement event to get further insights into the potential of social robots for traffic guidance. By iterating the design process based on the feedback received, we aim to implement a user-centered design process in which the robot's capabilities meet the expectations of citizens. Further efforts will focus on developing innovative methods to identify where the robot could be deployed and their underlying V2X communication. Ultimately, the robot will be deployed in real-world urban environments to evaluate its impact and efficacy in traffic management.

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