SEAN-VR: An Immersive Virtual Reality Experience for Evaluating Social Robot Navigation

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Figure 1: Our Virtual Reality (VR) demonstration system. A user controls a virtual avatar through VR in the Social Environment for Autonomous Navigation (SEAN). A robot in the simulation guides them to a destination in the virtual world.

ABSTRACT

We propose a demonstration of the Social Environment for Autonomous Navigation with Virtual Reality (VR) for advancing research in Human-Robot Interaction. In our demonstration, a user controls a virtual avatar in simulation and performs directed navigation tasks with a mobile robot in a warehouse environment. Our demonstration shows how researchers can leverage the immersive nature of VR to study robot navigation from a user-centered perspective in densely populated environments while avoiding physical safety concerns common with operating robots in the real world. This is important for studying interactions with robots driven by algorithms that are early in their development lifecycle.

KEYWORDS

virtual reality, social navigation, mobile robotics, demonstration

1 TECHNICAL OVERVIEW

Our proposed demonstration, SEAN-VR, incorporates an interactive Virtual Reality (VR) experience into the Social Environment for Autonomous Navigation 2.0 (SEAN 2.0). SEAN is a simulation environment designed for the training and evaluation of social navigation systems, which combines the rendering capabilities of Unity with the Robot Operating System for robot control [13]. By combining VR interactivity and SEAN 2.0, we can create immersive experiences where a user interacts with a mobile robot in simulation. The user can then provide feedback about their perception of the robot's behavior, based on their experience in the simulation.

Our demonstration is designed for participants to interact with the robot, in short, 1-2 minute sessions (Fig. 1). This will allow many people to try our demonstration throughout the conference. More specifically, the demonstration will occur as follows:

- A person interested in participating will be told that 1) they can interact with a mobile robot in simulation using a VR Head Mounted Display (VR HMD) and hand controllers to control a virtual avatar, 2) that normal or correct-to-normal vision without the use of glasses is required, and 3) no user data from the demonstration will be recorded. Any logs incidentally collected will be deleted afterwards. If the person does not accept these terms, then the demo will end; otherwise, it will proceed as described below.

- The user will be shown how to hold the controllers and wear the HMD. We will inform the user that they should verbally indicate if they become dizzy or disoriented, in which case we will stop the

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demonstration and help them remove the headset. The participant will put on the controllers and HMD.

• We will start the simulation and the user's avatar will be spawned nearby a model of a Kuri robot in a simulated warehouse. The onscreen instructions in the HMD will indicate that the user should find and follow the robot and observe its behavior.

• The user will follow the robot. The robot will perform different behaviors as it navigates to the goal. We expect some behaviors to elicit a positive view of the robot from the user, such as navigating efficiently to the goal. Other behaviors, such as robot spinning motion, are likely to elicit a negative view of the robot.

• Once the robot reaches the goal, or the episode times out in 120 seconds, the participant will be presented with several subjective questions about their perceptions of the robot, shown in the HMD.[1] A message that the demo is over will then be shown along with brief instructions to remove the HMD.

• We will help the user remove the HMD and controllers. Finally, we will ask several open-ended questions such as, "How immersive did the experience feel?" or "Did you feel like you were with a robot in a warehouse?" We will use this feedback to subjectively gauge the success of our demonstration; however, this open-ended feedback will not be recorded.

2 EQUIPMENT AND PERSONNEL

We will bring the following demonstration equipment:

- Vive Pro Eye HMD and controllers;
- 2x SteamVR 2.0 Base Stations with mounting stands;
- a laptop computer; and
- a short throw projector and a projector screen, to display the view from the HMD.

Overall, the demonstration requires a minimum of $3m \times 2m \times 3m$ and a maximum of $5m \times 5m \times 3m$ of space (w×d×h). The maximum power required is 200w. No additional networking, lighting, or sound is necessary.

The following individuals will support the demonstration:

- Qiping Zhang: PhD student and lead of the Vive Pro Eye VR control in SEAN 2.0.
- Nathan Tsoi: PhD student and the primary author of SEAN [11] and SEAN 2.0 [13].
- Marynel Vázquez: Assistant Professor and advisor of N. Tsoi and Q. Zhang at Yale University.

Although one person could feasibly run the demonstration, we will divide the work with one team member helping the participant use the HMD and controllers, another member controlling the software, and one more member describing what is occurring in the demonstration to the user and other nearby people.

3 NOVELTY

SEAN 2.0 allows users to specify complex, high-level behaviors for virtual pedestrians. The interaction of virtual pedestrians elicits *social situations*, which we formalized using propositional logic in prior work [13]. Social situations allow the training and evaluation of social navigation systems in a range of different contexts (e.g., in conversational group formations [10], situations where a robot crosses a path of pedestrians walking perpendicular to it [8], etc.). SEAN has seen adoption by many researchers, e.g., at Aalto University, Carnegie Mellon University, Ewha Womans University, Temple University, University of Los Andes, University of Toulouse, University of Twente, University of Virginia, and Yale University.

For this demonstration, we have added VR support to SEAN 2.0. Using the HMD and VR controllers, the user can control the motion of their virtual avatar in the 3D environment and look around.

Our integration of VR into SEAN 2.0 allows HRI researchers to study how humans perceive social robots in environments densely populated with other virtual pedestrians. Gaming is currently the most common application of VR with consumer-grade devices [17]. Further, prior research has explored the use of VR in areas such as studying human-human interactions [5] and HRI [15]. For example, prior work has focused on predicting head and eye gaze for social robot navigation [2], improving human-robot communication [14], and for telepresence control of a mobile robot [3].

4 IMPORTANCE AND USEFULNESS

The immersive nature of VR enables the study of mobile, social robots in crowded scenarios without risks such as colliding into nearby people and thereby minimizing risk of physical harm to users. This is particularly useful for researchers and robotic practitioners who would like to study human-robot interactions with robots that use algorithms that are early in their development lifecycle, that require exploration, or that offer no safety guarantees, such as popular learned navigation policies (e.g., [6, 7, 9]).

The evaluation of robotic systems that interact with humans requires undertanding the performance of the robot from a social interaction perspective. This performance is often measured through surveys that query users about subjective factors (e.g., their perception of the social appropriateness of the robot's behavior [1]). Previously, we evaluated social navigation policies from a human perspective by deploying SEAN simulations on the web using the SEAN Experimental Platform (SEAN-EP) [12] and collecting human feedback using online surveys. Experiencing a human-robot interaction in VR is different from a simulator deployed on the web, though, because VR is more immersive. In our future work using SEAN-VR for social robot navigation, we expect to get more rich human feedback about robot navigation than we could get with SEAN simulations rendered on a regular computer screen. Also, our system could promote wider adoption of VR for HRI, which could help clarify open questions like its suitability for HRI studies [16] and the effect that VR may have on participant's perceptions of proxemic behavior [4].

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[1]Participant responses to the questions will not be recorded.

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