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I Am the Robot: A VR Based Wizard of Oz System for the Humanoid Robot Pepper

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Abstract

This late-breaking report presents a Wizard of Oz control system that uses virtual reality equipment to operate the humanoid robot Pepper. The system enables control by mirroring the operator's movement within the physical space, including body and head rotation, and arm movements directly onto the robot. The system was evaluated in a study setup with two participant groups: users and operators. Results showed that the system was effective in simulating natural robot behaviour, while being intuitive and engaging.

CCS Concepts

• **Human-centered computing → HCI design and evaluation methods**; **Empirical studies in HCI**.

Keywords

wizard of oz, virtual reality, pepper, human-robot interaction

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1 Introduction

Recent advances in Artificial Intelligence (AI), machine learning, and robotics have contributed significantly to the development of humanoid robots, with growing applications in healthcare [8], service [12, 20], and education sectors [25]. However, conducting Human-Robot Interaction (HRI) studies with fully autonomous robots presents numerous challenges, as current AI technologies are not yet capable of supporting complex, real-time social behaviours in robots. There are several approaches to exploring future scenarios in cases where current technology is not yet sufficiently stable for reliable testing [14, 26]. The goal is often to uncover potential challenges and opportunities by making speculative leaps. A widely used method in this context is the Wizard of Oz (WoZ) technique [4], which is a deceptive approach in which users are led to believe they are interacting with an autonomous system, while a human operator is actually controlling the machine.

The aim of this project was to develop and evaluate a WoZ control system for the humanoid robot Pepper. A previous system developed by Thellman et al., enabled a human operator to control the robot in real time using Virtual Reality (VR) equipment and hand controllers, effectively mirroring their own movements [21]. While this system allowed for immersive robot control, it had several limitations: locomotion was controlled via a touchpad, video feedback lacked depth perception and demanded an external camera, and there was no functionality for audio input. Another VR system for Pepper, used hand tracking sensors for more natural hand control but only allowed for upper-body operation [10]. These constraints in the previous literature not only affect the operator's experience, but may also influence how autonomous the robot appears to the interactive partner.

This project builds on that work by addressing these limitations and aims to develop a natural WoZ system using mainly the wizard's body to control the robot as its own. The contributions of this late-breaking report are the VR-based system itself and an evaluation study from both the user and operator side of the interaction.

2 Background: Wizard of Oz

The primary rationale for employing the WoZ method in HRI is to simulate natural behaviour that current autonomous robots are incapable of performing. In a typical WoZ setup, a human operator—the 'wizard'—partially or fully controls the robot's behaviours (e.g. speech, movement, lighting, gestures, and sound) from a separate physical location. The wizard often perceives the environment through the robot's sensors, such as cameras and microphones, and controls the robot by monitoring joint states, initiating preprogrammed motion sequences, and triggers speech or text output. In essence, the wizard acts as an invisible puppeteer, enabling rich, interactive experiences that surpass the robot's current autonomous capabilities. Often, the robot is controlled via the standard platforms' own control interface, such as for NAO, Pepper and Furhat. However, many researchers build their own control systems to better meet the study conditions [e.g. 9, 13, 18, 22].

Although, WoZ methods have faced criticism for their lack of realism regarding robot autonomy [16], they can meaningfully inform autonomous system development when used with proper constraints and interface design [13]. Human control of robots appears to play an increasingly important role in future society. In recent years, particularly with the advancement of LLMs, wizards have been required to control humanoid robots to collect data for training large visual models [28]. Consequently, the technical and usability requirements of WoZ systems have grown, highlighting the need for ease of use, robustness, and sustainable working conditions.

2.1 VR WoZ Systems

VR applications has gained traction in HRI, offering novel ways to enhance communication, collaboration, and control between humans and robotic systems [e.g. 24]. VR enables intuitive and transparent interactions by providing visual cues, instructional overlays, and real-time feedback that can improve users' situational awareness and understanding of robot states [17]. Whether used for teleoperation [6], collaborative task planning [3], or programming by demonstration [7], VR supports more natural and efficient workflows by bridging the gap between human perception and robotic execution. Applications of VR in robotics span industrial automation [5], assistive technologies [1], healthcare [27], and educational settings [19]. As VR hardware and tracking technologies continue to advance, integration of VR in HRI promises to make robot control more accessible, safe, and human-centered across a broad range of use cases.

Thellman et al. explored a VR-based WoZ system designed to improve real-time responsiveness and social realism for the Pepper robot using the HTC Vive headset and handheld controllers. Preliminary tests with users showed that most participants felt their perspective shifted into the robot's body, creating a sense of embodiment. Participants also found the system intuitive, requiring minimal instructions, and reported that it provided a compelling experience of 'being the robot'. Another WoZ system for Pepper used Oculus Rift and markerless pose imitation with Leap Motion to track the user's upper body pose and replicate it in real time. The approach bypasses complex inverse kinematics by mapping human limb orientations directly to the robot's joints. The system was tested in two object manipulation tasks—grasping and pouring. Results showed that participants found the VR-based control easier to learn and more intuitive than kinesthetic guidance, especially for tasks requiring coordination of both robot arms. Participants also reported a higher sense of embodiment and comfort using the VR system [10].

3 Method

3.1 The System

The WoZ control system[1] is composed of four main components: the Pepper robot, VR equipment (using Meta Quest 2), and two computers—Computer1 and Computer2. These computers manage data processing and communication between Pepper and the VR setup. Computer1 runs a Unity-based C# application, while Computer2 runs a Python program.

The system address limitations identified from previous systems [10, 21], including locomotion, depth perception, audio input, body movements, and on-board cameras. To create an immersive experience for the operator controlling Pepper, visual and auditory feedback were central components. The operator's field of view consistently used a stereographic setup, enabling human-like depth perception, and to enable audio, a game object was connected to a UDP stream, ensuring that the received audio data from Pepper's surroundings was played through the VR headset. The physical movement of the robot was solved by the operator taking one step and the robot moving the same distance, and that Pepper's body rotated only when the operator's head turned beyond 45°, providing an easy way of moving the robot naturally around the room. Developing smooth and precise arm control for Pepper was one of the key challenges, and to improve accuracy, an iterative Inverse Kinematics (IK) solution was implemented.

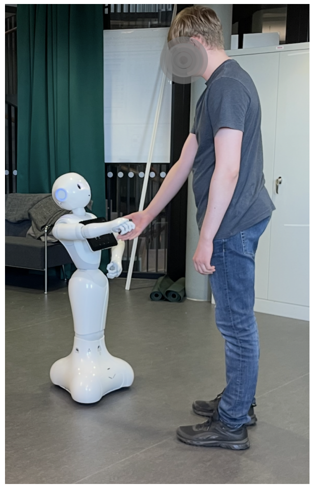
3.2 Evaluation Study

The study was conducted in accordance with the principles of the WoZ method. The operator controlled Pepper as if it were their own body, following the user's instructions. Pepper was placed in a separate room from the operator, so the user only had physical contact with Pepper and not with the operator. The user could give verbal instructions to Pepper, but the operator could only respond through the robots' body movements. Some of the instructions users gave during the test included; 'Can you [the robot] go to location X, look at/point to object X, spin around, hold up your arms, and/or nod/shake your head to answer yes/no to a given question'; while the instructions to the operator followed a protocol consisting of five steps: 1) nod Peppers head if one could hear the user, 2) shake Peppers head, 3) spin around once, 4) go to a chair a few meters away, and then return back to the user, and 5) hit an object hanging in a string from the ceiling. These steps were designed to give the operator a varied experience of the system's functionality. See

[1] Github repository for the control system: https://github.com/Kandidatarbete-27/vr-styrsystem-pepper.

Figure 1 for an example of how the interaction looked like. Before each session, the participants gave their informed written consent.

(a) Operator controlling Pepper.



(b) User interacting with Pepper.

Figure 1: WoZ setup.

3.2.1 Questionnaires. Before the study started, demographic data (age, gender, and prior experience with technology and robots on a 1–5 Likert-scale) were collected, and each participant completed both prior and post-study questionnaires. In total, there were four questionnaires: *User-Prior*, *User-Post*, *Operator-Prior*, and *Operator-Post*.

The User-Prior questionnaire consisted of the Negative Attitude Toward Robots Scale (NARS) [15]. NARS contain three sub-scales: negative attitudes toward *situations of interaction* with robots, negative attitudes toward the *social influence* of robots, and negative attitudes toward *emotions in interaction* with robots. NARS is comprised of five-choice items Likert-scale from 1) strongly disagree to 5) strongly agree. One question, 'Operating a robot in front of other people would make me nervous', was removed to not reveal the WoZ setup. The User-Post questionnaire was GODSPEED [2], which contains five sub-scales; *anthropomorphism* (ascribed human-likeness), *animacy* (the ascribed property of being sentient or alive), *likeability*, *perceived intelligence*, and *perceived safety*. GODSPEED employs a semantic differential method where respondents mark which out of two opposite pairs of adjectives best describes the robot, e.g. human-like versus machine-like, on a five-point Likert-scale. An additional question was included, asking whether the user believed the robot was autonomous or remotely controlled. At the end of the study, it was revealed that Pepper had been controlled in a WoZ setup.

The Operator-Prior questionnaire was designed using a 1–5 Likert-scale ('Strongly disagree' to 'Strongly agree'). The questionnaire focused on participants' prior experience, ethical views on using robot control systems, and expectations of the system. The Operator-Post questionnaire focused on how the participants experienced using the control system. Both questionnaires for operators can be seen in Table 2.

Statistical analysis was performed in IBM SPSS 30. Cronbach's α scores for NARS and GODSPEED resulted in .74 and .90 respectively (high internal validity).

3.2.2 Participants. The evaluation study was divided into two groups. The first group consisted of users (N = 11, *mean age* = 23.73, SD = 8.62, 36% men) who interacted with Pepper, and the second group consisted of operators (N = 10, *mean age* = 24.20, SD = 4.94, 90% men) who controlled the robot. The participants were students or faculty recruited through a convenience sample. They had substantial experience with technology in general, but less prior experience with robots.

4 Results

In this section, we firstly present on the results from the user perspective, followed by the operator perspective.

4.1 User Perspective

In Table 1, the results from the User-Prior questionnaire are presented. For the total score, the mean was 3.36 (SD = 0.54), indicating that users had slightly negative attitudes toward robots. Furthermore, it can be seen that users expressed a fear of robots' potential impact on society and culture (S2; M = 4.05, SD = 0.54), as well as scepticism toward developing emotional bonds with robots (S3; M = 3.60 SD = 0.88). Finally, S1 (negative feelings towards interacting with robots) was the only subscale that indicated a slight positive tendency among the average user, with a mean of 2.53 (SD = 0.64).

Table 1: Result of the user prior and post questionnaires.

Scale	Mean	SD
User-Prior: NARS	3.36	0.54
S1	2.53	0.64
S2	4.05	0.54
S3	3.60	0.88
User-Post: GODSPEED	2.97	0.57
Anthropomorphism	2.04	0.63
Animacy	2.67	0.62
Likeability	3.51	0.78
Perceived intelligence	3.58	0.70
Perceived safety	3.36	0.61

In Table 1, the results from the User-Post questionnaire are also presented. The results indicate that the average user seemed to have a neutral acceptance of Pepper. The total score had a mean of 2.97 (SD = 0.57). This is in line with previous GODSPEED results when interacting with Pepper [e.g. 11, 23], indicating a similar quality level by our WoZ system. Furthermore, 10 out of 11 users answered that the robot was autonomous, which suggests that our WoZ system enabled natural robot behaviour and did not elicit suspicion of human control.

4.2 Operator Perspective

4.2.1 Operator-Prior Questionnaire. The results from the questionnaire completed by the operators before controlling Pepper are

Table 2: Questions and results of operator prior and post questionnaires.

Nr.	Question	Mean	SD
	Operator-Prior		
1	Would you say that you have a lot of experience with virtual reality?	2.40	1.35
2	Would you say that you are more prone to motion sickness than other people?	2.50	1.78
3	Do you feel comfortable knowing that you will be controlling a robot?	4.60	0.52
4	Do you feel comfortable knowing that the user is unaware that you are controlling the robot?	3.90	0.99
5	Would you feel comfortable if the user found out afterward that you were controlling the robot?	4.40	0.70
6	Do you expect your new robot-body to be able to pick something up from the ground?	4.00	1.16
7	Do you expect your new robot-body to mimic your movements?	4.50	0.71
	Operator-Post		
1	Did it work well to control the robot?	3.10	1.37
2	Did it feel like the robot followed your movements?	3.40	1.17
3	Did it feel like there was a long delay before the robot moved like your real body?	3.70	0.68
4	Did the video quality feel good?	1.80	0.79
5	Did it feel like you had depth perception?	2.60	0.84
6	Did you experience a strong feeling of motion sickness?	1.80	1.03
7	Did it feel like your consciousness existed within the robot?	2.00	0.94

summarised in Table 2. Operators reported limited VR experience (M = 2.40, SD = 1.35) and a low tendency toward motion sickness (M = 2.50, SD = 1.78).

Question 3, 4 and 5 concerned the operators' feelings and ethical considerations regarding the control system. Here, operators gave high average ratings. For question 3, which asked whether they felt comfortable about controlling a robot, the average response was 4.60 (SD = 0.52), indicating that participants felt very comfortable with this task. For question 4, asking whether they were comfortable with the user being unaware that the robot was being controlled, the mean was 3.90 (SD = 0.99), suggesting that the operators were generally comfortable with this scenario. Question 5, which asked if they would be comfortable with the user finding out afterwards that the robot was remotely controlled, operators gave an average response of 4.40 (SD = 0.70). This shows that operators would feel very comfortable revealing them to the users as the wizard of the robot after the experiment.

The final two questions, addressed the operators' expectations for the robot's movement capabilities and the control system. The results show that operators had generally high expectations. On the question about whether they expected their new robot body to be able to pick up objects from the ground, the mean was 4.00 (SD = 1.16), indicating a high level of expectation for the system. This result further indicates high expectations of Pepper, since, e.g. the robot is unable to reach the ground. For the question about whether they expected their new robot body to mimic their movements, the mean was 4.50 (SD = 0.71), suggesting very high expectations regarding the control system's latency and responsiveness.

4.2.2 Operator-Post Questionnaire. The results from the questions answered by operators after controlling Pepper are also summarised in Table 2. The overall experience of how well the robot could be controlled appeared to be neutral, with operators giving an average score of 3.10 (SD = 1.37).

Operators experienced that Pepper followed their movements slightly better than neutral, with a mean of 3.40 (SD = 1.17). However, several operators reported experiencing noticeable latency, as reflected in a higher mean score of 3.70 (SD = 0.68). The video quality was perceived as problematic, with a low mean score of 1.80 (SD = 0.79). Regarding question 5, which asked whether depth perception was present, the average score was slightly below neutral at 2.60 (SD = 0.84). Few participants experienced strong motion sickness, as indicated by a mean score of 1.80 (SD = 1.03). Finally, operators gave an average score of 2.00 (SD = 0.94) on question 7, suggesting that they did not feel as though their consciousness was present within the robot.

5 Discussion and Conclusion

In this late-breaking report, we present a VR-based WoZ system for controlling the humanoid robot Pepper, targeting the limitations in previous work [10, 21], and performed an evaluation study. The results from the evaluation study show that the WoZ operator was able to successfully act as an autonomous Pepper robot using their own body. However, the operators did not experience a shifted sense of self from their own body to the robot, in contrast to the findings of Thellman et al. [21]. Two possible reasons for this discrepancy are that, in the prior study, participants neither moved around in the environment nor performed specific tasks.

Another reason for this could be that even when the robot did accurately reflect the operator's actions, it was sometimes difficult for the operators to visually interpret this. The arms were especially affected, as the camera's limited periphery meant they were often out of sight. Since humans heavily rely on visual feedback, one way to reduce uncertainty about how well the robot mirrors movements, we suggest to integrate a small visualization of the full robot model into a corner of the operator's VR interface. This would provide a more immediate understanding of the robot's position and movements in real time.

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