

HRISudio: A System for Conducting Human-Robot Interaction Studies using the Wizard-of-Oz Model

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Abstract—Human-robot interaction (HRI) research plays a pivotal role in shaping how robots communicate and collaborate with humans. However, conducting HRI studies, particularly those employing the Wizard-of-Oz (WoZ) technique, presents challenges due to technical complexities and specialized expertise requirements. To address these challenges, we propose HRISudio, a novel web-based platform designed to streamline the design, execution, and analysis of WoZ experiments in HRI research. HRISudio offers an intuitive interface for experiment creation, real-time control and monitoring during live sessions, and comprehensive data logging and playback tools for analysis and reproducibility. By lowering technical barriers and promoting collaboration, HRISudio aims to accelerate innovation in human-centered robotics research, empowering researchers to explore novel HRI concepts efficiently and effectively.

I. INTRODUCTION

Human-robot interaction (HRI) is becoming an increasingly important field of study, essential for understanding how robots should communicate, collaborate, and coexist with people. However, conducting HRI studies poses significant challenges, especially regarding the implementation of robot autonomy. The Wizard-of-Oz (WoZ) technique has emerged as a valuable experimental paradigm, allowing experimenters to simulate autonomous behaviors with a human operator, or “wizard” simulating the autonomous behavior of a robot, creating the illusion of an intelligent system for study participants. This enables rapid prototyping and evaluation of HRI concepts, without needing to build complex robot intelligence.

While the WoZ technique is a powerful tool, conducting such experiments poses significant challenges. Researchers frequently face barriers related to the specialized tools and robotics expertise needed to orchestrate WoZ studies. Existing solutions often rely on low-level robot operating systems, limited proprietary platforms, or extensive custom coding, hindering accessibility for domain experts without extensive programming backgrounds.

Through a comprehensive review of current literature, we have identified a pressing need for a platform that simplifies the process of designing, executing, and analyzing experiments in the field of HRI research, by reducing technical barriers while enhancing reproducibility and collaboration across different robotics hardware and research groups. To address this gap, we are developing a novel web-based platform that enables intuitive configuration and operation

of WoZ studies for HRI researchers and non-programmers alike. Our platform aims to handle the complexities of interfacing with a multitude of robotics platforms via the Robot Operating System (ROS), presenting users with a high-level, user-friendly interface for experiment design, live control and monitoring, and comprehensive post-study analysis.

The primary contributions of our work include a drag-and-drop visual programming interface for designing experiments without extensive coding, real-time control and observation capabilities during live experiment sessions, as well as comprehensive data logging and playback tools for analysis and reproducibility. With collaboration and reproducibility in mind, these features aim to maximize accessibility to HRI research while enforcing a standard of scientific integrity.

By lowering the barriers to entry for non-programming domain experts, our platform seeks to accelerate research and innovation in human-centered robotics. The following sections will outline our proposed system design, experimental workflow plans, implementation progress, and future directions for this work.

II. STATE OF THE ART

As HRI research continues to gain prominence, the WoZ technique has emerged as a valuable experimental paradigm. By simulating the autonomous robot behaviors through a human operator, or “wizard”, researchers can rapidly prototype and evaluate novel HRI concepts without the need for complex autonomous system implementation. However, conducting WoZ studies poses significant challenges, and existing solutions often present barriers related to specialized tools, limited flexibility, or extensive programming requirements.

Several frameworks have been proposed to facilitate WoZ experiments in HRI. Polonius [2] offers a graphical user interface for wizards to control robots based on predefined finite state machine scripts. While built on the modular ROS platform, Polonius lacks enhanced tools for experiment design, data analysis, and cross-platform collaboration. NottReal [3], designed for voice user interface research, provides scripting capabilities and visual feedback to enhance the illusion of autonomy for participants. However, its scope is limited to audio-based interactions.

WoZ4U [5] presents a user-friendly GUI for controlling Aldebaran’s Pepper robot, lowering the barrier for non-programmers to conduct HRI studies. However, its applicability is restricted to Aldebaran platforms, hindering hardware flexibility. OpenWoZ [1] proposes a runtime-configurable framework with a multi-client architecture, en-

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abling evaluators to modify robot behaviors during experiments. While promoting standardization, OpenWoZ still requires programming expertise for customization.

A systematic review by Reik [4] highlights prevalent WoZ applications in natural language processing and non-verbal behavior simulation but identifies gaps in methodological rigor, such as lack of wizard training and error measurement. The review proposes reporting guidelines to enhance transparency and reproducibility in WoZ studies.

Despite these efforts, a comprehensive solution that simplifies the entire experimental workflow while promoting reproducibility and collaboration across diverse robotics platforms remains elusive. Existing frameworks often require extensive programming knowledge, lack robust tools for experiment design and analysis, or are limited to specific hardware platforms. Our proposed system aims to bridge this gap by providing an accessible, web-based interface for intuitive experiment creation, live operation, and comprehensive data analysis, while seamlessly integrating with various robotics platforms through ROS. By lowering technical barriers and facilitating cross-platform collaboration, our solution seeks to accelerate innovation in human-centered robotics research.

III. EXPERIMENTAL WORKFLOW

A. Experimental architecture

Fig. III-A. A sample experiment examining comprehension over varying modes of interaction

To provide a structured and intuitive framework for designing WoZ experiments in HRI research, our platform introduces a hierarchical organization of experimental elements. At the highest level, an *experiment* represents the complete scientific study being conducted.

Within each experiment, researchers can define a series of *steps*, which represent conceptual stages or phases of the experimental protocol. These *steps* serve as logical containers for grouping and sequencing the specific *actions* that the robot or the wizard must perform throughout the duration of the study, as illustrated in Figure III-A.

At the lowest level, *actions* constitute the elemental units of the experimental workflow. Each [action] corresponds to a specific physical or virtual task that the robot or wizard must execute. These tasks encompass a spectrum of activities, including robot movements, verbal interactions, or awaiting participant input.

By breaking down the experimental procedure into this hierarchical structure, researchers can design complex HRI studies while maintaining a clear set of instructions for each wizard. The *steps* provide a high-level overview of the experimental phases, while the *actions* encapsulate the granular tasks and behaviors required from the robot or the wizard.

B. Experiment creation process

To enable intuitive and streamlined experiment design, our platform features a user-friendly interface for creating

and configuring WoZ experiments in HRI research. This interface leverages a visual programming system, allowing researchers to construct their experiments using a drag-and-drop approach.

The core of the experiment creation process will include a library of pre-defined action components, representing common tasks and behaviors that robots and wizards may need to perform during an experiment, including robot movements, speech synthesis, and instructions for the wizard. Researchers are able to drag and drop these action components onto a canvas, arranging them into sequences that define the steps of their experiment. Each step can contain one or more actions, enabling the construction of complex experimental protocols.

In addition to arranging actions and steps, the interface will provide configuration options for each component, allowing researchers to go beyond the pre-defined action library to customize parameters. This configuration system will be accompanied by contextual help and documentation, guiding researchers through the process and providing examples or best practices for designing functional experiments.

C. Live experiment operation

During live experiment sessions, our platform offers multiple synchronized views to streamline operation, observation, and data collection. The primary view, tailored for the wizard, enables seamless control over the robot's actions and behaviors. Displaying the current step of the experiment along with associated actions, this interface facilitates intuitive navigation and note-taking. The wizard can progress through actions sequentially or manually trigger specific actions based on contextual cues or participant responses. Additionally, controls for robot movements, speech synthesis, and other essential functions are readily accessible.

In parallel, the observer view supports live monitoring, note-taking, and potential interventions by additional researchers or personnel involved in the experiment. This feature ensures the option of continuous oversight without disrupting the participant's experience or the wizard's control. Given the web-based nature of our platform, multiple observers can concurrently access the observer view, enhancing collaboration and enabling comprehensive data collection and analysis.

D. Data logging, playback, and annotation

Throughout the live experiment session, the platform will automatically log various data streams, including timestamped records of all executed actions and experimental events, exposed robot sensor data, and audio and video recordings of the participant's interactions with the robot. This logged data will be stored in JavaScript Object Notation (JSON) files kept in a secure encrypted location, enabling efficient post-experiment analysis and data mining without compromising the privacy of the subjects or researchers.

After an experiment session, researchers will have access to a dedicated playback interface. This interface will allow them to review the recorded data streams synchronously,

enabling a holistic understanding of the experiment’s progression. This interface will support features such as: synchronized playback of audio, video, and sensor data streams, visual annotations and note taking capabilities, navigation and scrubbing through the recorded data with the ability to mark and note significant events or observations, and export options for selected data segments or annotations.

By providing robust data logging and playback capabilities, our platform aims to enhance the rigor and reproducibility of HRI WoZ experiments.

IV. PROPOSED SYSTEM DESIGN

A. High-level architecture

Fig. IV-B. The high-level system architecture of HRIStudio

The system is designed as a full-stack web application using the Next.js React framework. The frontend handles the user interface components like the experiment designer, monitoring dashboard, and analysis tools. The backend API logic, built using Next functions and tRPC, manages experiment data, user authentication, and communication with a ROS interface component. The ROS interface, implemented as a separate C++ node, translates high-level actions from the web application into low-level robot commands, sensor data, and protocols, abstracting the complexities of different robotics platforms. This modular architecture aims to leverage the benefits of Next’s server-side rendering, improved performance, and security, while enabling integration with various robotic platforms through ROS.

B. Key design principles

In developing this novel platform for WoZ experiments in HRI research, we have identified several guiding design principles to ensure its effectiveness, usability, and widespread adoption.

Foremost, simplicity and accessibility are of the highest priority. Our primary objective is to lower the barrier of entry for non-programming domain experts who wish to conduct HRI studies. The platform will provide an intuitive and user-friendly interface, abstracting users from the intricacies of robot programming and autonomous system development.

Furthermore, our design principles prioritize reproducibility and collaboration. To achieve these objectives, we foster scientific integrity through extensive experiment logging and seamless export and sharing functionalities.

Additionally, our platform embraces a hardware-agnostic approach. Leveraging a modular and extensible architecture, it seamlessly integrates with a wide array of consumer and research robots through the ROS interface, ensuring compatibility with already available hardware.

V. IMPLEMENTATION PROGRESS

While the full realization of the proposed platform is still a work in progress, we have made notable strides in several key areas to lay the groundwork for its development.

Our efforts thus far have primarily focused on exploring the core technologies, creating user interface mockups, and establishing a development roadmap.

A. Core technologies

We have chosen to leverage the Next.js React framework for building the web application element of our platform. Next provides several advantages, including server-side rendering, improved performance, and enhanced security compared to traditional single-page applications. With the application being available on the web, we aim to provide compatibility with most hardware currently available to researchers. Additionally, the framework’s built-in support for API routes and its ability to integrate with tRPC will simplify the development of APIs for interfacing with the ROS interface.

For the robot control layer, we plan to utilize ROS as the communication and control interface. ROS offers a modular and extensible architecture, enabling seamless integration with a multitude of consumer and research robotics platforms. By leveraging the widespread adoption of ROS in the robotics community, our platform aims to support a wide range of robots out-of-the-box, with the support of the already existing ROS community available for new robot implementations.

B. User interface mockups

A significant portion of our efforts have been dedicated to designing intuitive and user-friendly interface mockups for the platform’s key components. We have created wireframes and prototypes using Figma for the frontend’s dashboard, drag-and-drop experiment designer, the real-time experiment monitoring and control dashboard, and the data playback and annotation tools.

The experiment designer mockups feature a visual programming canvas where researchers can construct their experiments by dragging and dropping pre-defined action components. These components represent common tasks and behaviors, such as robot movements, speech synthesis, and instructions for the wizard. The mockups also include configuration panels for customizing the parameters of each action component.

For the live experiment operation, we have designed mockups that provide synchronized views for the wizard and observers. The wizard view presents an intuitive step-based interface that walks the wizard through the experiment as specified by the designer, triggering actions, and controlling the robot, while the observer view facilitates real-time monitoring and note taking.

Our data playback and annotation mockups showcase features for synchronized playback of recorded data streams, including audio, video, and applicable sensor data. These mockups incorporate visual and textual annotations, scrubbing capabilities, and data export options to support comprehensive post-experiment analysis and reproducibility.

C. Development roadmap

While the UI mockups have laid a solid foundation, we still anticipate several challenges in transforming these designs into a fully functional platform. One of the primary challenges will be integrating the Next web application with the ROS interface, and handling the bi-directional communication between the two systems. We anticipate leveraging tRPC and WebSockets to facilitate real-time data exchange and robot control.

Another significant challenge lies in developing the drag-and-drop experiment designer and encoding the experimental procedures into a standardized, shareable format. We plan to explore existing visual programming libraries and develop custom components to enable intuitive experiment construction and configuration.

Additionally, implementing robust data logging and playback capabilities will require integrating with various data streams, such as audio, video, and sensor data, while ensuring synchronization and efficient storage and retrieval mechanisms.

To address these challenges, our development roadmap includes:

- Establishing a stable Next codebase and integrating tRPC for API development.
- Implementing a C++ ROS node for handling robot communication and control.
- Developing the drag-and-drop experiment designer using visual programming libraries and custom components.
- Integrating data logging mechanisms for capturing experimental data streams.
- Building the data playback and annotation tools with synchronization and export capabilities.
- Documenting the platform and creating tutorials and guidelines for researchers to adopt and contribute to the system.

By following this roadmap and addressing the identified challenges, we aim to transform the proposed platform into a fully functional and accessible tool for conducting WoZ experiments in HRI research, empowering researchers and fostering collaboration within the community.

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