AURORA: A Platform for Advanced User-driven Robotics Online Research and Assessment

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***Abstract*—AURORA is a software platform, that facilitates scalable deployment of robotic simulations over the web for the Human-Robot Interaction (HRI) community. As robotics is becoming increasingly important in various disciplines, there is a growing need for accessible and scalable research methods. Traditional experiments often require expensive hardware and in-person participation, limiting accessibility and participant diversity. Our platform allows researchers from different fields to easily provide HRI experiences by deploying online studies with robotic simulations paired with customizable surveys, allowing end users worldwide to interact with these simulations. Our platform is entirely open source and can be hosted locally, providing flexibility and control of the research environment. Since AURORA is implemented with Docker, it is platform-independent. By offering a user-friendly interface that can be deployed and used without extensive technical expertise, our platform reduces costs, increases participant diversity, and improves the reproducibility of research in the HRI community.**

***Index Terms*—software; robots; simulation software; research and development; cooperative systems; internet**

I. Background

Robots are increasingly becoming an integral part of various sectors, including manufacturing, healthcare and domestic environments [1]–[5]. As their role in modern society expands, robotics research becomes more important [6], [7]. Particularly in the field of human-robot interaction (HRI), understanding how humans interact with robots remains an important challenge [5], [8]–[10].

However, conducting meaningful experiments in robotics and HRI faces significant challenges. High costs and limited availability of hardware can be prohibitive for researchers [11]–[13]. As HRI in an interdisciplinary context is becoming increasingly important, for many researchers who do not have a technical background, there may be skill barriers to performing research that involves HRI [14], [15].

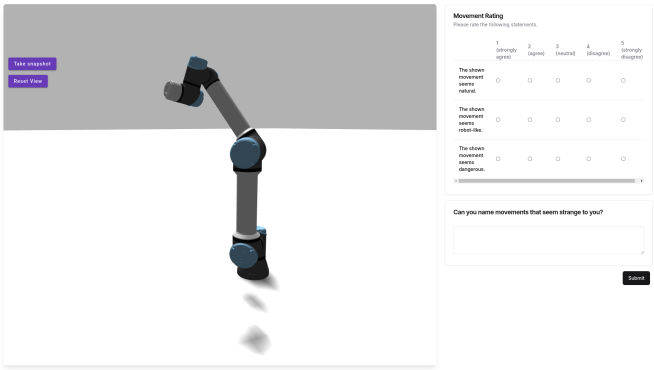

Fig. 1. **GUI for end users**: Screenshot of survey page containing a robotics simulation and questions.

Additionally, the requirement for participants to be physically present limits accessibility and reduces participant diversity, often confining studies to specific geographic locations [11], [16], [17]. These limitations can introduce bias and limit the generalisability of research findings [4], [16]–[20].

Web-based robotics simulations offer a practical solution to these challenges by providing a cost-effective, scalable means for conducting HRI experiments [11], [12], [16], [21]–[25]. They allow a wider range of participants from different backgrounds to engage in studies, generating richer and more representative data. By eliminating the need for physical presence, these simulations also reduce the environmental impact by minimizing travel and resource consumption [12]. While web-based simulations may not fully replicate the complexity and immersion of real-world interactions, they still allow researchers to focus on specific aspects and can expand the reach of HRI research [21] [26].

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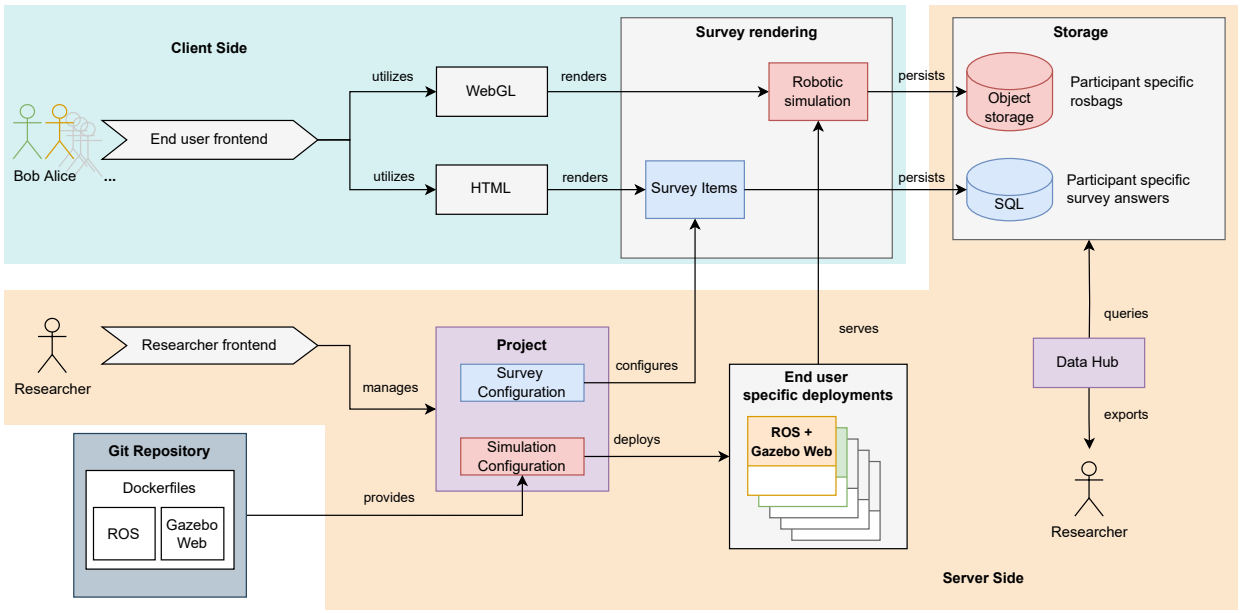

Fig. 2. **Architecture of the AURORA platform:** The diagram shows the interaction between researchers, end users, and platform components. Components placed within a light blue field represent those rendered client-side, while components within the orange field are rendered on the server side. Researchers manage projects (survey and simulation configurations) via the researcher frontend. The simulation configurations are provides by a Git repository, which the researcher can choose. End users interact with studies through the end user frontend in a browser. The browser utilizes different tools to render the survey and simulation based on the information from the server. Each end user has a specific deployment (ROS + Gazebo Web) with which they interact. This example depicts a study containing both a simulation and a survey; Data from simulations are stored in object storage, and survey answers are stored in an SQL database for later export by researchers.

Deploying web-based robotics simulations for HRI research typically involves complex setups that require significant technical expertise and resources [11], [21]. These barriers may prevent researchers, especially those from diverse disciplines or with limited technical backgrounds, from leveraging online robotics simulations effectively.

To deconstruct these barriers, we developed a platform for Advanced User-driven Robotics Online Research and Assessment (AURORA), that allows researchers to conduct remote HRI experiments and gather participant's feedback through integrated surveys. Though newly developed, the platform holds significant potential for advancing HRI research and beyond. An established platform that enables HRI research to be distributed globally could help to create a better framework for the reproducibility of research in the field [14], [27]. For example, it could be used for remote evaluation of robot behavior, simulation of interactive human-robot task learning, as an educational tool for teaching robotics concepts, or other applications [28]–[32].

II. Purpose

The primary purpose of the AURORA platform is to streamline and facilitate the deployment of web-based robotics simulations, making them more accessible and efficient for researchers across various disciplines. By providing a user-friendly environment for deploying web-based simulations, our platform enables a wide range of applications.

In addition to deploying simulations, our platform offers the ability for conducting studies, facilitated by an integrated, comprehensive survey tool. In combination with our platforms ability to store the simulation data, this allows researchers to design and implement studies that collect both quantitative and qualitative data in HRI experiments, ultimately driving progress in the field. the AURORA platform provides three main functionalities:

1) **Web Deployment of Simulations**: Enables researchers to deploy robotics simulations or other web-based applications online.
2) **Web Deployment of Surveys**: Enables researchers to conduct standalone surveys.
3) **Studies integrating Simulations and Surveys**: Allows researchers to conduct studies that integrate robotics simulations and surveys in a single interface for the end user (as shown in figure 2).

Furthermore, our platform is designed with a commitment to sustainable research practices. It reduces the environmental footprint of HRI studies by reducing the need for travel and physical resources. The platform incorporates ethical data collection methods, ensuring that participant data are handled securely and responsibly. By providing an accessible and scalable solution, our platform enables HRI research to engage with participants from diverse demographics and backgrounds, fostering inclusion and enhancing the generalisability of findings. Our platform provides the following key features:

- **Accessible Deployment of Simulations**: Simplifies deploying web-based robotics simulations without requiring deep technological expertise, thereby improving accessi-

bility and lowering barriers to entry in HRI research.

- **Inclusive Participant Engagement**: Allows end users to easily interact with simulations through their web browsers, supporting inclusivity in research design by reaching a more diverse and broader participant pool.
- **Integrated Data Collection**: Incorporates a built-in survey tool for capturing data securely and ethically, facilitating comprehensive data collection while ensuring compliance with privacy standards.
- **Resource-Efficient Scalability**: Utilizes dynamic resource allocation to scale computational resources as needed, minimizing the ecological footprint by ensuring resources are used only when necessary.
- **Flexible Use**: The platform is entirely open source and can be hosted locally, providing researchers with the flexibility to customize and control their research environment according to their specific needs.

III. Characteristics

The AURORA platform is designed as a open source web application with a Python [33] and FastAPI [34] backend, using Docker for containerized and platform-independent deployment. On top of that, a self-hosted Kubernetes [35] cluster based on k3d [36] (a lightweight and containerized wrapper for k3s [37]) is used, that the researcher can easily deploy the infrastructure. While the setup, using k3d, allows for easy initialization and management of the system, the use of Kubernetes in combination with the inter-compatibility to other Kubernetes installations and providers enables flexible hosting options. Once set up, the application provides a graphical user interface (GUI) for the researcher, which is accessible through any web browser, offering full control of the platform's features without requiring advanced technical knowledge.

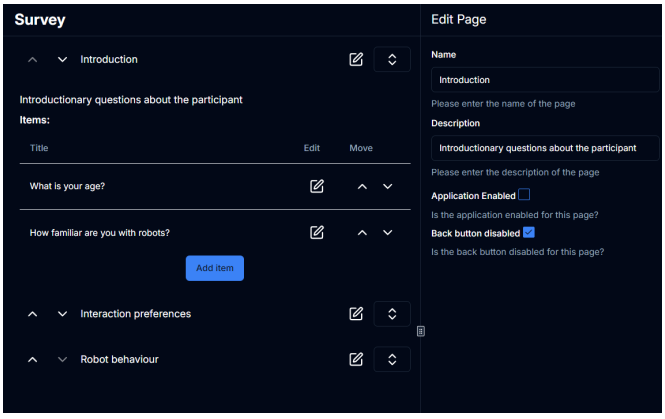

Fig. 3. **GUI for Page Manager**: On the left side is the navigation tab, the section in the middle allows managing survey items, and the right side provides options for editing the page.

A. Robot Simulation Deployment and Configuration

The AURORA platform supports the deployment of robotic simulations containing simulations built up on either ROS 1 or ROS 2 [38]. The platform only supports simulation environments that use client-side rendering through WebGL [39], such as gazebo-web [40]. This ensures that all simulations run interactively within the end user's browser, while the ROS environment and backend processes operate on the server side.

To set up a simulation, researchers must configure their robotic simulation development environment in one or more Dockerfile definitions and upload these to an existing or self-hosted supported Git provider (currently GitHub and GitLab). A barebone ROS and Gazebo robotic simulation with the necessary configuration set up and on which you can build is provided together with the platform. Integration of the robotic simulation is achieved by providing the repository URL and access token, allowing the platform to also pull non-public repositories, build the Docker images, and push them to a private Docker image registry within the Kubernetes cluster. Each Dockerfile can be configured to expose a port, which will be mapped to individual subdomain routes providing access to web interfaces, such as gazebo-web, through the platform.

The platform automatically generates Rosbag recordings for all ROS topics. The simulation configuration is translated into a custom Kubernetes object that acts as a reusable template for deploying simulation containers in participant studies.

B. Scalable Simulation Deployment

The AURORA platform leverages deployment configurations defined within the Kubernetes cluster to efficiently deploy and manage personalized simulation containers for each user. When a end user accesses a simulation page, the platform dynamically creates a Kubernetes object that maps the user to the relevant simulation configuration, as set up by the researcher, deploying one or multiple isolated container with dedicated services and ingress rules to ensure accessibility via a unique subdomain. This deployment remains active for the duration of the session and is terminated when the user completes the questionnaire or leaves. Rosbag recordings for specified ROS topics are transferred to a self hosted S3 object storage powered by MinIO before container removal. Other S3 providers may be configured.

The platform dynamically scales by adding or removing user specific Kubernetes deployments based on demand, with resource limits ensuring the number of concurrent simulations is managed to optimize system performance and stability. Kubernetes may be further configured to scale across multiple nodes, further enhancing scalability and resilience.

C. Integrated Survey Tool

The AURORA platform offers a comprehensive survey tool that empowers researchers to create, deploy, and manage surveys. Most importantly, it provides the opportunity to integrate simulations directly into the survey interface. This allows participants to interact with simulations and respond to related survey items seamlessly within the same interface. The tool is organized around two primary components: Survey Items and Projects.

1) Survey Items: Survey items are independent from projects and reusable. They can be added in multiple projects. In the Item Manager, researchers can create, edit and delete survey items, which are stored in a centralized database. Additionally, researchers can import survey items using CSV files. Several widely used questionnaires [41]–[46] are provided for direct upload. Survey items come in various types:

- **Text**: Presents informational or instructional content to participants as text, rendered in HTML to allow for diverse visual customization options.
- **Image**: Adds Images via URL.
- **Video**: Adds Videos via URL.
- **Question**: Collects participant responses.

For question items, the platform supports multiple formats to accommodate diverse data collection needs:

- **Free-text Question**: Allows participants to provide free-form textual responses.
- **Multiple Choice Question**: Participants select one or more options from a predefined list.
- **Rating Scale Question**: Participants rate items along a numerical scale (e.g., from 1 to 100).
- **Matrix Question**: Participants evaluate multiple items using consistent response options in a grid format (e.g. Likert Scale).

2) Projects: Projects serve as the primary organizational unit within the AURORA platform, encapsulating all elements necessary for a study or simulation. Each project integrates a simulation configuration, a survey, and pages. Within each survey, the Page Manager facilitates the creation and organization of pages, enabling researchers to structure the survey flow effectively by adding, deleting, and reordering pages.

Within the Page Manager, researchers can either add survey items or add a simulation on individual pages (as shown in figure 3). Items can be reordered or removed as needed, providing flexibility in designing the survey's content and sequence. This hierarchical structure allows for the construction of comprehensive surveys tailored to specific research objectives, seamlessly integrating simulations and survey items within the same interface.

D. Data Management and Export

All end user interactions, including survey responses and simulation data, are securely stored within the project's database. All data are saved within a project and can be downloaded from the data hub. This data include rosbag files from robotics simulation interactions and survey data collected from end users. All data are linked by IDs of the end users. Researchers can export these datasets.

E. User Interface and Accessibility

The AURORA platform's user interface is built using SvelteKit [47] and Tailwind CSS [48], providing a responsive and accessible experience for both end users and researchers. The end user interface offers basic access to simulations and surveys (as shown in figure 1). The researcher interface provides an overview of active simulations and studies, as well as tools for managing survey items, building simulations, and exporting data.

F. Security and Privacy

The security and privacy of user data are critical aspects of the AURORA platform's architecture. Designed for self-hosting, the platform allows researchers to retain full control over their data and comply with organizational security policies. All communications between end users and the platform are encrypted using HTTPS with Transport Layer Security (TLS), protecting data from interception and tampering. Participant access to the platform is managed through the use of unique links provided to end users. These links contain a UUID, to prevent link guessing on other surveys. The domain used for these links is independent of the AURORA platform and corresponds to the researcher's server, ensuring that researchers have full control over the hosting environment. The platform can be configured to include participant, survey and session IDs as URL parameters, facilitating seamless integration with external participant recruitment platforms, like Prolific. This allows for efficient tracking and management of participant responses in coordination with these platforms. In cases where no participant ID is provided in the link, the platform internally generates a unique identifier when data storage in the database is necessary. This mechanism ensures that all participant interactions are appropriately logged and associated with unique identifiers without requiring any personally identifiable information (PII). The platform features a password-protected researcher interface and we provide an option for the researchers to create a consent form, which is deployed to the end users. The integration of these security measures provides a secure environment for conducting remote human-robot interaction studies. These features ensure that end user data is protected, access is appropriately restricted, and the platform remains secure against potential threats.

IV. Code

The platform's code is open-source and available under the MIT license. It is hosted on GitHub[1] and can be freely accessed, along with documentation that provides detailed instructions for installation and usage. The code will be actively maintained and contributions from the community are welcomed. Several open source libraries, all of which are documented in the GitHub repository, were used. Additionally, an example simulation is provided, which functions as a bare bone template to build ROS and Gazebo projects on.

V. Usage Notes

Researchers using this platform for studies and participant data collection must handle data ethically and in accordance with applicable laws. Informed consent should be obtained in accordance with relevant legal frameworks to ensure that participants understand the study and how the data will be used.

[1]https://github.com/interactiveroboticsowl/AURORA

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