Comparing Human Input in RViz and Virtual Reality Interfaces for 3D Object Manipulation Tasks

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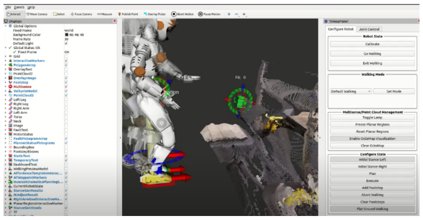
***Abstract*— Effective human-in-the-loop robot control requires intuitive and easy to use interfaces. We present a within-subjects user study design to compare the ease of use of interfaces for human-robot teleoperation, specifically the ROS 3D visualization tool RViz and a virtual reality interface. Our proposed study will determine which interface is easiest to use and minimizes operator cognitive load in shared autonomy tasks.**

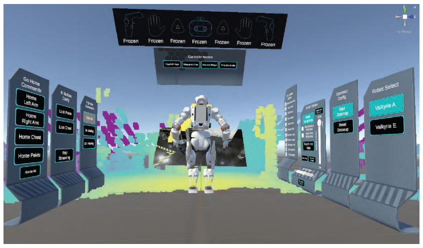
I. INTRODUCTION

The robotics community is making advances towards *taskable* robots: intelligent robots capable of completing any commanded task. There are several dimensions along which we can measure robot capabilities, one of which is ease of interaction [22]. *Ease of interaction* allows robot systems to be effectively commanded for shared autonomy tasks. Virtual reality (VR) and augmented reality (AR) have gained interest as interfaces for collaborative tasks between a human and a robot [4], [33], [11], as they allow users to intuitively interact with artifacts in 3D spaces [9]. Research shows that AR can lessen cognitive load, improve learning, and improve task performance in a wide variety of domains [5], [8], [31], [32]. In robotics, many works explore using AR [15], [18], [37], [34] and VR [16], [35], [38], [39], [3] as intuitive interfaces for teleoperation of robots. AR and VR exist along Milgram's reality-virtuality continuum [24], [37], which categorizes how interfaces use physical and virtual elements. Of interest to our study is NASA Johnson Space Center's VR interface [20], which is considered *augmented virtuality* (AV) along Milgram's spectrum. AV incorporates physical elements within virtual environments [11] and connects to both AR and VR research. Though this interface is AV, we will refer to it as NASA's VR interface within this paper.

Desktop keyboard-and-mouse interfaces [29], such as RViz [21] (Figure 1a), used for robot interaction can be cumbersome and impose high cognitive load on operators. One work shows that approximately 50% of time spent operating robots in RViz is spent clicking and orienting the interface before commanding the robot [19]. Due to the limitations of RViz, researchers aim to improve the interface using elements of AR [10]. AR/VR interfaces (Figure 1b) situate users within a mixed or virtual reality environment. For robotics applications, AR/VR interfaces allow operators to manipulate the robot through human movements. Previous works demonstrate that AR reduces task times [6] and cognitive load [27] in human-robot collaborative tasks.



(a) ROS 3D visualization tool, RViz. Visualizations can be toggled on the left and high-level robot states can be commanded on the right. Robot state and visualizations are seen in the middle.



(b) NASA's VR interface. Menus surround the operator to control Valkyrie and enable shared autonomy tools. Robot state, data visualizations, and augmented reality views are displayed.

Fig. 1: Interfaces for shared autonomy tasks on NASA Johnson Space Center's Valkyrie robot.

For effective communication in 3D robot manipulation tasks, the interface itself significantly impacts how humans interact with robot systems [30]. Many interface comparisons support lessened cognitive load in AR interfaces [5] and comparisons of AR/VR interfaces and desktop control interfaces [17] use the NASA Task Load Index (NASA TLX) for evaluating task workload [30]. These previous works explore specific robotics tasks such as debugging [17] or arm motion control [30]. Within this study, we aim to compare the use of RViz and NASA's VR interface in *shared autonomy tasks*.

In this paper, we present a within-subjects user study design to compare RViz and NASA's VR interface. Participants will perform several tasks in both RViz and VR. Data will be gathered on task performance and cognitive load, in order to evaluate which of the two interfaces users find more effective and easier to use in 3D robot manipulation tasks. Through this study, we aim to inform roboticists about ease of use and

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Shared Autonomy Tool	Definition
Waypoint Navigation*	Navigate to given trajectory endpoint
Joystick Navigation*	Navigate using a controller
Teleoperation*	Control the robot's arm/head motions
Stance Generation	Determine where the robot should stand to reach a target pose
AT Registration	Determine world pose of an object or *affordance template* (AT) [13], [12]

TABLE I: Shared autonomy tools to be evaluated in the proposed study. Tools marked with * will be presented first in a random order; all others will be presented second in the fixed order listed above.

Shared Autonomy Task	Description
Waypoint Navigation	Navigate between given start and end points
Joystick Navigation	Navigate between given start and end points
Teleoperation	Control robot to pick up disruptor
Stance Generation	Generate stances, select stance, navigate to planned stance, teleop to pick up disruptor
AT Registration	Register disruptor, generate stances for waypoint in registered affordance template, navigate to planned stance
Pick Up Disruptor	Navigate to table and pick up disruptor

TABLE II: Shared autonomy tasks for the proposed study. Tasks will be presented after training on the appropriate tool. The final open-ended task will allow participants to choose what tools to use.

cognitive load of shared autonomy tasks in RViz and VR.

II. EXPERIMENT PROCEDURES

A. Experiment Hypotheses

Our proposed study will test the following hypotheses:

- Hypothesis 1: Participants operating robots will experience less cognitive load completing tasks in VR than in RViz, as measured by a modified NASA TLX survey.
- Hypothesis 2: Participants will have better situational awareness in RViz than in VR, as measured by a modified NASA TLX survey.
- Hypothesis 3: Task completion time will be faster in VR than in RViz, indicating less temporal demand and more efficient task completion when in VR than in RViz.
- Hypothesis 4: The number of controller/mouse clicks will be less in VR than in RViz.
- Hypothesis 5: Through semi-structured post-assessment interviews, participants will disclose that VR supported greater ease of use and higher efficency than RViz.

B. Experiment Setting

The purpose of the proposed within-subjects user study is to compare two interfaces for robot control and determine which interface better supports shared autonomy tools, minimizes operator cognitive load, and allows for faster task completion. We will be comparing the ROS 3D visualization tool RViz and a virtual reality (VR) interface developed for NASA Johnson Space Center's Valkyrie robot [28], [19], [20]. RViz is a standard ROS desktop keyboard-and-mouse interface (Figure 1a). Participants will interact with the VR interface (Figure 1b) using a VR headset and controllers. Table I shows the shared autonomy tools participants will use. We aim to recruit 25 NASA early career or intern participants with different levels of programming and robotics experience varying from first time to expert users.

Participants will interact with each shared autonomy tool in both interfaces through training and task performance, then complete a post-survey. For example, if a participant is randomly assigned to perform tasks first in VR and then in RViz, they would interact with the teleoperation (teleop) tool in the following phases: 1) teleop training in VR; 2) teleop training in RViz; 3) teleop task in VR; 4) teleop task in RViz; 5) survey on teleop in VR; and 6) survey on teleop in RViz. Shared autonomy task descriptions can be seen in Table II.

After completing each task, participants will complete an adapted NASA TLX for measuring cognitive load [14], [25], [7], [27]. The NASA TLX evaluates workload by asking participants to rate their experience among a number of scales. Our survey for evaluating cognitive load uses the following scales: mental demand, physical demand, temporal demand, effort, frustration, performance, and an added scale for situational awareness (modelled after existing scales [26]). Situational awareness is important for collaborative robot tasks so operators understand what is happening in the 3D environment for safety and effective task completion. Participants will rate their experiences along each scale to allow us to compute a cognitive load score for each task in both interfaces. Task completion time and controller/mouse clicks will also be measured.

III. DISCUSSION AND CONCLUSION

Qualitative feedback from the NASA Valkyrie team indicates the advantages of using VR to command robots over RViz for operators with programming and robotics experience. Performing object manipulation tasks in VR takes less time than the equivalent task in RViz. Navigation takes approximately equivalent time in both interfaces, indicating that each likely has strengths for shared autonomy tasks.

Initial work involves refining our study design and recruiting participants. Future work involves exploring how ease of interaction for operators affects how accurately robots perform shared autonomy tasks. Models of human input such as steering law [1], [2] and Fitts' law [23] interpret how human interaction affects task accuracy in different interfaces. Due to the challenges of modelling 3D human movements, Fitts' law has not yet been extended to model 3D *manipulation tasks* [36], [40]. We will use data collected in our user study to identify relevant human factors in 3D shared autonomy tasks. These human factors may be applied to an extension of Fitts' law for 3D manipulation tasks. Exploring the strengths of robot control interfaces for shared autonomy tasks could significantly improve ease of interaction between human operators and robot systems.

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