2024 IEEE Conference on Telepresence
CalTech, USA. November 16-17, 2024

2024 IEEE Conference on Telepresence | 979-8-3315-2824-9/24/$31.00 ©2024 IEEE | DOI: 10.1109/Telepresence63209.2024.10841783

THUMBDRIVER: Telepresence Robot Control with a Finger-Worn Mouse

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***Abstract*—THUMBDRIVER enables users to remotely operate a telepresence robot using an off-the-shelf finger-wearable mouse. The system carefully maps typical mouse actions to various robot operations, facilitating smooth and precise control. In a user study, we compared THUMBDRIVER with a keyboard-based control method. The results showed that THUMBDRIVER required significantly fewer actions to perform teleoperation tasks, leading to reduced average task completion times. Participants found THUMBDRIVER to be faster, more precise, and easier to learn and use. All participants expressed a preference for continuing to use THUMBDRIVER for operating telepresence robots.**

***Index Terms*—robotics, telepresence, mouse, keyboard, operation, steering**

I. INTRODUCTION

Telepresence robots are gaining popularity for their ability to let users to remotely attend events, visit places, and interact with people. While traditional telecommunication systems, such as videotelephony, phone calls, or video conferencing platforms, can offer similar capabilities, telepresence robots provide superior immersion, enhanced engagement, and a stronger sense of embodiment [1, 2]. The global COVID-19 pandemic further accelerated their adoption and development, as they became essential for maintaining social connections while adhering to social distancing measures [3]. As a result, their use is expanding across various applications, including education [4, 5], healthcare [6, 7], independent living [8]–[10], and accessibility [11, 12].

Despite their potential, the widespread adoption of telepresence robots is limited by the challenges involved in operating them. Previous research has shown that users often struggle with maneuvering the robot, particularly when it comes to turning, reversing, and maintaining or adjusting its speed [1, 13]–[16]. These difficulties frequently result in the robot getting stuck or causing collisions. Additionally, since telepresence robots are often used in social settings, such as conferences or meetings, where they must navigate among people, these mishaps can have serious consequences.

Another limitation of current teleoperation systems is their reliance on a stationary setup. Most systems use a keyboard and mouse-based interface, which requires users to sit at a desk and perform repeated keystrokes and clicks to control the robot [17]. This can be inconvenient and physically demanding, especially for people with limited motor skills.

Wearable devices could offer a promising solution to some of the challenges associated with the operation of telepresence robots. Since these devices are worn on different parts of the body, users have continuous access to them. They eliminate the need for a stationary setup, allowing for operation on the go. In addition, when paired with intuitive and low-effort actions, wearable devices can be more accessible to people with limited motor skills.

In response to these needs, we developed THUMBDRIVER, a system that enables the operation of telepresence robots using a commercially available finger-wearable mouse. The device is worn on either the middle or index finger and is operated with the thumb. Through a comprehensive literature review and an iterative design process, we carefully mapped typical mouse actions to the corresponding robot operations to ensure smooth and precise control. We then evaluated THUMBDRIVER in a user study, comparing its performance with that of a commonly used keyboard-based method.

II. RELATED WORK

A substantial body of research has focused on the development and applications of telepresence robots. In contrast, comparatively less attention has been given to the design of effective control and teleoperation systems. Most current systems rely on desktop interfaces operated by keyboards and mice, which require interaction with controls such as buttons, sliders, and dials to navigate and manipulate robots. While functional, these interfaces often demand significant cognitive and manual effort, highlighting the need for more intuitive and efficient teleoperation solutions [17].

At times, researchers combined desktop setups with fully or semi-autonomous robot functions. In fully autonomous systems, operators select a destination and the robot automatically plans the path and navigates to it [18, 19]. In semi-autonomous systems, operators guide the robot to the destination, while the robot autonomously avoids obstacles along the way [16]. Unfortunately, these methods are not consistently evaluated in controlled studies, making it challenging to assess and rank them based on quantitative data and subjective analysis.

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Joysticks have also been used to control telepresence robots, taking advantage of their ability to provide continuous input. This contrasts with the binary input of a keyboard or mouse, allowing for smoother and more nuanced adjustments. Both one- and two-hand joystick configurations have been explored [20]. In certain instances, joysticks have been combined with additional controls. For example, a treadmill could be used to regulate the robot's speed, while the joystick handles steering [21]. Another approach uses a head-mounted display (HMD) to adjust the robot's camera view with head movements [22]. Although these solutions are innovative, they require specialized setups and equipment. In addition, significant training is often necessary to master the controls.

Some researchers have also explored the use of smartphones to control telepresence robots. Given their ubiquity, they offer the potential for convenient, on-the-go interaction. Ainasoja et al. developed three control methods: a touchscreen version of the desktop interface, a tilt-based method in which users tilt the device to steer the robot, and a hybrid method that combines tilt with a spring slider for velocity control [23]. In an evaluation, the tilt-based method demonstrated faster performance, but users showed a preference for the hybrid method. Later work proposed a different tilt-based method by meticulously mapping tilt actions to various robot controls [17]. In a comparative evaluation, this method was faster, more accurate, and preferred by users than the default touchscreen interface. In addition, some researchers have investigated the use of voice commands on smartphones to operate telepresence robots [24]. Although these methods are promising, they may not be accessible to older adults or individuals with motor disabilities.

Recent research has explored innovative technologies and sensors for teleoperation. Zhang et al. [25] achieved hands-free control for people with motor disabilities using an HMD to translate user gaze movements into the corresponding robot actions. Beraldo et al. [26] developed an EEG-based teleoperation system that uses brain signals along with advanced path planning algorithms to improve safety and reliability.

Efforts to improve teleoperation include incorporating haptic feedback through steering wheels or pedals, offering tactile sensations to enhance control and situational awareness [27, 28]. However, these solutions are not widely adopted due to their high cost, complexity, and sensitivity to environmental conditions, which limit practicality. The specialized hardware required is also cumbersome, further discouraging widespread use. As a result, these approaches remain largely experimental.

III. ThumbDriver

Finger mice, primarily popular in Asian markets, are commercially available devices worn on the middle finger with the optical sensor facing the fingertip (Fig. 3a). Similar to traditional mice, they feature a scroll wheel and left and right buttons, operated with the thumb. To move the cursor, users bend their finger to position the optical sensor on a flat surface, using it as a regular mouse.

ThumbDriver utilizes a finger mouse to operate telepresence robots. Table I presents the mapping of mouse actions to robot movements. The mouse actions and the corresponding robot movements are intuitive. Users press the right and left buttons to turn the robot right and left by $15°$, respectively. This discretized rotation allows for precise movements, unlike continuous rotation that can often lead to over-rotation. Users scroll the wheel up and down to increase and decrease speed, respectively. The wheel controls velocity by accumulating the up and down scrolls and scaling them to the robot's linear velocity (V) using the equation $V_{Robot} = k \cdot S$, where V_{Robot} represents the robot's linear velocity, $k = 0.1$ is a scaling factor, and S is the accumulated scroll value.

TABLE I: Mapping of device actions to robot movements.

Robot Action	**Default**	**ThumbDriver**
Activate, deactivate	‘I’, ‘K’	Left + Right click
Increase velocity	‘W’	Scroll up
Decrease velocity	‘X’	Scroll down
Reverse	‘,’	Scroll down to $-V$
Rotate right as moving forward	‘L’	Right click
Rotate right as moving backward	‘.’	
Rotate left as moving forward	‘J’	Left click
Rotate left as moving backward	‘M’	

These mappings were refined through prior research and an iterative design process to ensure smooth and precise control. To activate or deactivate control, users press the left and right mouse buttons simultaneously. This action was chosen as it is not usually used in desktop interfaces, reducing the likelihood of accidental activations.

IV. User Study

We conducted a study to compare ThumbDriver with a traditional keyboard-based teleoperation method.

(a) Default (b) ThumbDriver

Fig. 1: A participant operating a simulated telepresence robot using both the proposed and the keyboard-based method.

A. Participants

We recruited eight participants for the study (Fig. 1). Four of them identified as men and four as women. Their ages ranged from 25 to 35 years (M = 29, SD = 3.6). None of them owned or used a robot. One participant had previous experience with a finger-wearable mouse. Participants were compensated with US $10 for their involvement in the study.

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B. Design

The study used a within-subjects design. The independent variable was the teleoperation method, with two levels: default and THUMBDRIVER. With each method, participants operated the robot through two obstacle paths. Both the order of the methods and the obstacle paths were counterbalanced using a Latin square to eliminate any potential effects of practice. The dependent variables were the following performance metrics:

- **Task completion time** is the average time participants took to complete one obstacle path, measured in minutes.
- **Actions per task** is the average number of actions needed to complete one obstacle course. An action includes any user interactions, such as scrolling the scroll wheel or pressing mouse or keyboard buttons.
- **Collisions per task** indicate the average number of times the robot bumped into obstacles.

C. Implementation

We used the Ohmni simulation package [29] to develop a 3D environment for the study. The control software was created using the Robot Operating System (ROS)[1], with the 3D simulation built in Gazebo[2] and the visualization managed by RViz[3]. The simulated robot is an Ohmni telepresence robot (Fig. 3b) equipped with forward and downward facing cameras, a laser scanner sensor, and a display. The default method uses the `teleop_twist_keyboard` ROS package[4], which allows keyboard interaction to publish control commands to the ROS topic `cmd_vel` for maneuvering the robot. The keyboard-based method used the default key mapping provided by this package (Table I). Notably, the system enables increasing or decreasing the robot's linear velocity by 10% by pressing the 'W' and 'X' keys, respectively. The system also allows simultaneous movement and rotation of the robot to the right and left while moving forward or backward using dedicated keys. In contrast, we created a custom ROS node to control the robot with THUMBDRIVER, following the mapping discussed earlier in Section III. This custom node processes input from the finger mouse and translates it into control commands for the robot.

D. Obstacle Course

We designed two obstacle courses within the simulated environment to compare the methods (Fig. 2). The environment simulates an office space with a walled entrance, an office room, and an open work area featuring benches, desks, and a cabinet. The courses were carefully structured to require the use of all essential robot actions, such as rotating and reversing, to navigate obstacles. In addition, the open corridor-like area between the benches, free of obstacles, allowed users to increase speed.

[1]https://www.ros.org
[2]https://gazebosim.org
[3]https://wiki.ros.org/rviz
[4]http://wiki.ros.org/teleop_twist_keyboard

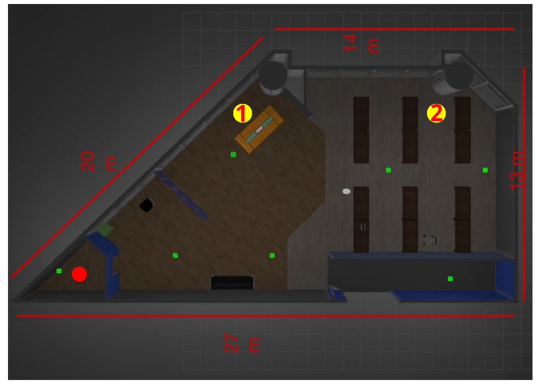

Fig. 2: The simulated environment, showing dimensions and the obstacle courses used in the study. All participants began at the red spot, navigated to the yellow spots marked as obstacle course 1 or 2, and then returned to the starting point.

E. Apparatus

The study used a Chicmine wireless finger mouse (Fig. 3a) operating on a 2.4 GHz frequency band. Its optical tracking had a resolution of 1600 DPI and could function at a maximum distance of 10 meters. The finger mouse is compact, measuring approximately 60×30×30 mm, and includes two buttons and a scrolling wheel for target selection and scrolling. Both teleoperation methods were tested on an Inspiron 13 7000 Series laptop with an Intel Core i7 processor, 12GB RAM, and a 1366×768 screen resolution on a 13.3-inch screen, running the Ubuntu 18.04.6 LTS operating system (Fig. 1).

(a) Finger Mouse (b) Ohmni Robot

Fig. 3: The finger-wearable mouse and the telepresence robot (simulated in the study) used in this work.

F. Procedure

The study was conducted in a quiet computer lab. Upon arrival, participants received an overview of the study procedure and gave informed consent before completing a demographic and technology usage questionnaire.

We then demonstrated the teleoperation system that they would be using in the simulated environment. Participants practiced with the system for 2–3 minutes before starting the first obstacle course. They were instructed to steer to the

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target and then return to the starting point. After completing the first course, the second obstacle course was loaded. Participants were instructed to perform the tasks as quickly and accurately as possible, avoiding collisions with obstacles. They relied on the simulated video feeds from the robot's cameras to navigate through the obstacle courses (Fig. 4).

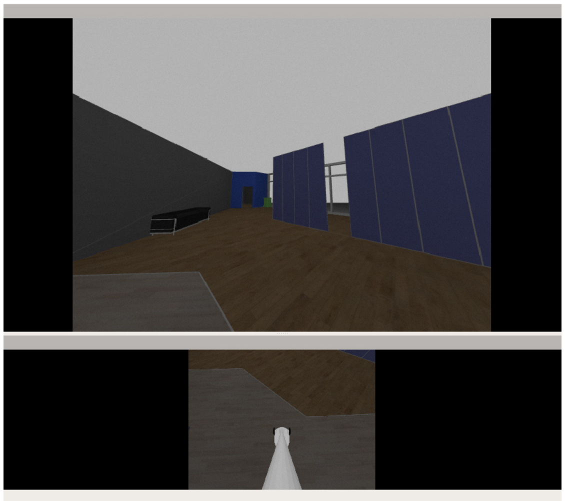

Fig. 4: The robot control graphical user interface (GUI) used with both methods. The top section displays the forward-facing camera view, while the bottom section displays the downward-facing camera view.

After completion of the tasks with the first method, participants were introduced to the second method and given another practice session. The study then proceeded with the same procedure as above. The order of the methods and obstacle courses was counterbalanced to minimize order effects.

Upon completion of the user study, participants filled out a custom questionnaire developed based on the System Usability Scale (SUS) [30]. They rated the two methods on perceived speed, accuracy, learnability, ease of use, and willingness to use, using a 5-point Likert scale.

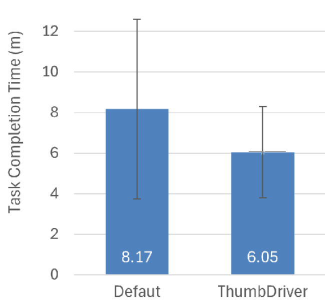

Fig. 5: Average task completion time for the two methods, with error bars representing ±1 standard deviation (SD).

V. Results

We conducted a two-sided paired sample t-test on study data and a Wilcoxon signed rank test on questionnaire data to determine statistical significance. Effect sizes are reported for all results [31]. For the t-test, Cohen's d is used, with $d = 0.2$, $d = 0.5$, and $d = 0.8$ corresponding to small, medium, and large effects, respectively. For the Wilcoxon signed-rank test, Pearson's correlation coefficient (r) is used, where $r = 0.1$, $r = 0.3$, and $r = 0.5$ correspond to small, medium, and large effects, respectively.

A. Task Completion Time

A t-test failed to identify a significant effect of the method on task completion time ($t = 1.75, df = 15, p > .05, d = 4.8$). But a one-sided t-test revealed near-statistical significance ($p = .05$). On average, participants took 8.17 minutes (SD = 4.42) using the default method and 6.05 minutes (SD = 2.25) using ThumbDriver. Fig. 5 illustrates these findings.

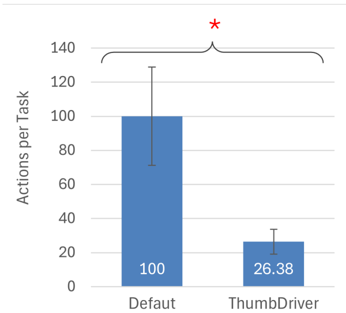

Fig. 6: Average number of actions per task using the methods. Error bars represent ±1 standard deviation (SD). A red asterisk denotes a statistically significant difference.

B. Actions per Task

A paired sample t-test identified a significant effect of the method on actions per task ($t = 10.23, df = 15, p < .001, d = 28.8$). On average, participants performed 100 actions (SD = 28.86) with the default method and 26.38 actions (SD = 7.30) with the ThumbDriver method to complete a task. Fig. 6 illustrates these results.

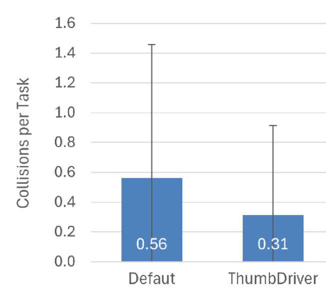

Fig. 7: Average number of collisions per task for the two methods. Error bars represent ±1 standard deviation (SD).

C. Collisions per Task

A t-test failed to identify a significant effect of the method on collisions per task ($t = 0.85, df = 15, p > .05, d = 1.2$). The average number of collisions per task was 0.56 (SD

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= 0.89) with the default method and 0.31 (SD = 0.6) with ThumbDriver. Fig. 7 illustrates these results.

D. Usability

A Wilcoxon signed-rank test identified a significant effect of the method on perceived speed ($z = -2.56, p < .05, r = 0.91$), perceived accuracy ($z = -2.43, p < .05, r = 0.86$), learnability ($z = -2.4, p < .05, r = 0.85$), ease-of-use ($z = -2.38, p < .05, r = 0.84$), and willingness-to-use ($z = -2.59, p < .05, r = 0.91$). All participants favored ThumbDriver over the default method in all aspects. Fig. 8 illustrates these findings.

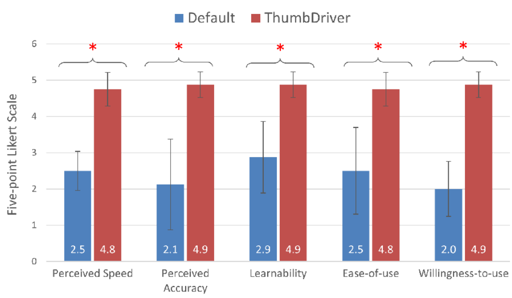

Fig. 8: Average perceived usability ratings of the two methods, measured on a 5-point Likert scale (1 = "strongly disagree", 5 = "strongly agree"). Error bars represent ± 1 standard deviation. Red asterisks indicate statistically significant differences.

VI. Discussion

ThumbDriver outperformed the default method in all aspects of the user study. It yielded a 26% faster task completion time compared to the default method (Fig. 5). Although this difference was not statistically significant in a two-tailed test, a near-significant result in the one-tailed test suggests that this difference may reach significance with a larger sample size. Participants also noticed this difference, as reflected in their significantly higher perceived speed rating for ThumbDriver compared to the default method (Fig. 8). The faster completion time is likely due to the significantly fewer actions required by ThumbDriver compared to the default method. Specifically, ThumbDriver required 74% fewer actions to complete a task than the default method (Fig. 6). A participant (male, 28 years) noted that ThumbDriver is much faster than the default method due to the use of the scroll wheel. This feature reduces the number of keystrokes required to perform a task, significantly decreasing both the effort and time needed to complete it.

ThumbDriver demonstrated greater precision compared to the default method, with participants causing 45% fewer collisions (Fig. 7). However, this difference was not statistically significant, even in a one-tailed test. Despite the lack of statistical significance, nearly all participants commented on the improved precision of ThumbDriver. A participant (female, 29 years) mentioned that she prefer the method as *"it offers more precision in movement, especially when it comes to making turns or going backwards."*

All participants preferred ThumbDriver over the default method in every aspect (Fig. 8). They found it not only faster and more precise but also easier to learn. One participant (female, 25 years) attributed this to the system's use of fewer buttons and its intuitive mapping. Furthermore, all participants found ThumbDriver significantly easier to use than the default method. A participant (female, 25 years) noted that the method was much easier to control, allowing for smoother movements, easier direction changes, and better speed control.

There were also some criticisms of the method. One participant (male, 35 years) noted that extended use of ThumbDriver could be physically demanding, leading to discomfort. Despite this, all participants expressed a preference for using ThumbDriver to control telepresence robots, describing the system as *"smooth," "easy,"* and *"perfect."* They also envisioned various potential applications for the control system. One participant (male, 35 years) suggested integrating virtual reality with ThumbDriver to enhance the operation of the telepresence robot. He believed that this combination could greatly improve user experience and precision in navigating complex environments.

VII. Limitations

There are several limitations to this work. First, the small sample size limits the generalizability of the results. However, the large effect size for the statistically significant findings suggests that these effects are likely to hold with a larger and more diverse sample.

Another limitation is that the comparative study focused solely on ThumbDriver and a traditional keyboard-based control method. This excludes other advanced control systems, such as joystick-based interfaces or those incorporating haptic feedback, which could offer a more comprehensive evaluation of ThumbDriver's performance across various contexts.

Lastly, the study was conducted in a controlled lab environment, which may not fully capture the complexities of real-world conditions. Future research should test the method in more varied and dynamic settings to better assess its practical applications and limitations.

VIII. Conclusion

We developed ThumbDriver, a teleoperation method for controlling telepresence robots using a finger-wearable mouse. This method maps mouse actions to robot movements, drawing on previous research and extensive lab trials to ensure smooth and precise control. To evaluate its performance, we compared ThumbDriver with a traditional keyboard-based method. The findings showed that ThumbDriver was faster, required fewer actions, and provided better precision. Participants reported a more efficient and accurate control experience, finding ThumbDriver easier to learn and use due to the intuitive design of the system. They expressed a strong preference for ThumbDriver and a desire to continue using it for telepresence robot control. These results affirm ThumbDriver as a viable solution.

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IX. Future Work

In future work, we plan to address the limitations outlined in Section VII . This includes increasing our sample size and exploring additional control methods for a more comprehensive evaluation of THUMBDRIVER. We also intend to adapt the system for virtual reality, as participants expressed interest in this integration.

Furthermore, we will develop features that allow users to customize keyboard controls, recognizing that some users may have preferences shaped by their experience with games or other interfaces.

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