

Partial Finger Involvement Reflects into Grasping Tasks Performance and Accuracy

L. Boban¹, M. Delahaye¹ and R. Boulic¹

¹École Polytechnique Fédérale de Lausanne (EPFL), Immersive Interaction Research Group (IIG), Switzerland

Abstract

This paper presents a user study comparing a grasping algorithm we adapted for the Valve Index controller to common grasping approaches using the HTC Vive Wand or the Oculus Quest's Computer Vision-based finger tracking. It involved 24 participants performing two widely known manipulation tasks for each device: "Pick and Place" and "Grab and Reorient". Our results place our Index Controller approach as a good trade-off between the other two approaches regarding completion time and accuracy.

CCS Concepts

• **Human-centered computing** → *User studies; Virtual reality; Interaction techniques;*

1. Introduction

We present a user study assessing the Valve Index Controller, a recent VR controller device providing the ability to use partial finger mobility to interact with the virtual environment. This device is compared to two other types of devices where one device does not allow finger mobility (HTC Vive Wand) and the other uses a Computer Vision (CV) approach (Oculus Quest) allowing full finger mobility.

2. Related Work

Previous literature shows that hand-held controllers outperform CV in terms of speed regardless of the simpler hand animation it produces [LNA*19]. Furthermore, to maximize the subjective feeling that the virtual body moves as one's do, known as the Sense of Agency (SoA), [AHTL16] showed that it is better to avoid any mismatch between a user's action and its transcription in the virtual environment and that the quality of this transcription is more valuable than the amount of movements allowed.

3. Experiment

Setup. We adapted the grasping algorithm from [HUWK08] that we enhanced to allow users to push objects or hold them within the hand without closing our hand. Furthermore, we increased the realism of the interaction by maintaining virtual fingers outside of the grasped object (see Figure 1 for examples).

For the comparison, the HTC Vive Wand used the default SteamVR's grasping method which simply requires to press a trigger to grab an object close to the hand. It does not address interpenetrations nor enforces the hand contact with the grasped object.

Regarding the Oculus Quest, we used a custom grasping algorithm

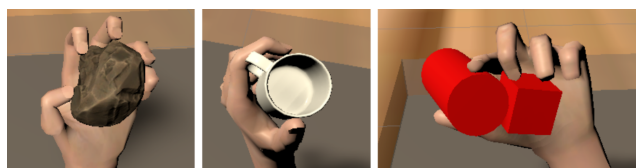


Figure 1: Grasping examples using the Valve Index controller grasping approach

based on collision normal points between fingers and objects as no public asset was available at the time of the experiment. This solution is somewhat similar to the solution we implemented for the Valve Index Controller and also addresses interpenetrations issues.

Finally, for a fair comparison, we provided similar feedback for all cases (i.e. object coloring, audio feedback, and controller vibrations when applicable).

Hypotheses. Performance was measured as the time required to perform the task, and accuracy as the delta error between final position and actual position of the object placement. The SoA was calculated using the questionnaire and the formula from [GFP18]. We formulated the following hypotheses hinted at by the literature:

H1 - Performance:

HTC Vive Wand > Valve Index Controller > Oculus Quest

H2 - Accuracy:

HTC Vive Wand > Valve Index Controller > Oculus Quest

H3 - SoA:

Valve Index Controller > HTC Vive Wand > Oculus Quest



Figure 2: The two experimental tasks: Pick and Place (left), Grab and Reorient (right)

Experimental protocol. Each participant had to perform both "Pick and Place" and "Grab and Reorient" tasks in a randomized order with each system condition (Figure 2). Thus we used a within-groups design where each subject had to follow each of the six conditions (two tasks \times three devices). Each bloc was composed of 10 trials and preceded with a short training of two minutes. The study was conducted over twenty-four subjects (9 women) aged between 18 and 33 years old. All subjects were right-handed but one. A preview of the task is available here: <https://youtu.be/ZcfBuopT3mA>

4. Results

As each dataset of recorded measures could not be considered as drawn from a normal distribution (D'Agostino's K^2 test) all statistical tests that were performed are non-parametric tests. The same also applied for the data from the questionnaire as it used discrete answers.

Thus the analysis pattern is the following: 1) We tested the equality of samples' median (Kruskal Wallis). 2) When it failed, we conducted a post-hoc analysis using pair-wise comparison (Mann-Whitney U) to highlight different samples. 3) We ordered those different samples using one-sided comparisons (Wilcoxon).

H1 - Performance. We observed for the "Pick and Place" task a significant difference between the HTC Vive Wand and other systems ($p < 10^{-8}$). One-sided tests ($p < 10^{-21}$) ordered approaches as:

HTC Vive Wand > Valve Index Controller, Oculus Quest

Pairwise comparisons and one-sided tests were all significant ($p < 10^{-4}$) for the other task. Thus we observed:

HTC Vive Wand > Valve Index Controller > Oculus Quest

H2 - Accuracy. We observed significant pairwise comparison and one-sided tests ($p < 10^{-3}$) leading to, in both tasks:

HTC Vive Wand > Valve Index Controller > Oculus Quest

H3 - Sense of Agency. We observed for the "Pick and Place" task only a significant difference between the Valve Index Controller and the Oculus Quest ($p \simeq 0.006$) and the one-sided test ($p \simeq 0.0003$) gave us:

Oculus Quest > Valve Index Controller

For the other task, only the pair Valve Index Controller and HTC Vive Wand ($p \simeq 0.017$) was significantly different. The corresponding one-sided test ($p \simeq 0.017$) gave:

HTC Vive Wand > Valve Index Controller

A binomial tests is used by paring each device type (A, B) and considering the frequency with which A 's score is higher than B 's one. Those tests rejected the null hypothesis (H_0 : the previous frequency follows a binomial distribution with $p = 0.5$) for couples involving the Valve Index Controller (both $p < 0.007$). Finally, the two associated one-sided binomial tests ($p \simeq 0.003$) gave us:

HTC Vive Wand, Oculus Quest > Valve Index Controller

5. Conclusion

Our user study allowed us to mainly validate our first hypothesis about performance placing our approach with the Valve Index Controller below the one using the HTC Vive Wand and above the one of the Oculus Quest. This supports prior work placing controller above CV input methods in term of task completion time [LNA*19]. Only the absence of significant order between the Oculus Quest and the Valve Index Controller on the "Pick and Place" lacks to fully accept this hypothesis.

This study also confirmed our second hypothesis about accuracy, ranking the HTC Vive Wand above the Valve Index Controller and the Oculus Quest at the third place.

Finally, our last hypothesis was surprisingly rejected: for the SoA the approach involving the Valve Index Controllers was outperformed by the one using the Oculus Quest. This can be explained by the specific difficulty to pinch objects with Index controller, as subjects easily mastered this grasp pose with the Oculus Quest. The HTC Vive Wand also provides better SoA than the Valve Index Controller for the "Grab and Reorient" task, here confirming the dominance of a good motion mapping rather than a large set of available DoFs [AHTL16].

Results from this study imply that the Valve Index Controller's intermediate finger mobility design is reflected in equally intermediate performances and accuracy compared to the HTC Vive Wand and the Oculus Quest.

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