Mobile Haptic Device for Large Virtual Environments

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Abstract

Introduction:

Most of the haptic devices are grounded and have a limited workspace and are not suitable for human-scale interactions [5] in VE. Few solutions found in the literature for the workspace problem of haptic devices are such as a fixed table approach [5], control algorithms [1], and a robotic approach [3]. However, these methods have limitations, such as design complexity and discontinued haptic feedback. Hence, we propose a hybrid approach combing robotic control and haptic control algorithms with a simple design to solve a workspace issue of the haptic devices. Existing robotic methods analyze the haptic system without considering human in the system control loop. However, the load and the response of the system can vary based on user interaction. Hence, we adapted the psychophysical method [2] to quantify the human perception when the haptic device renders force and through which we analyzed the haptic system performance and the efficiency of the proposed method.

Method:

The workspace of the grounded haptic device is extended in real-time VR applications through simultaneously shifting its physical and virtual workspace using a mobile robot and a position based workspace drift algorithm, respectively, as showed in Figure 1. When the device reaches its workspace limit, the robot moves to shift the haptic device physically until the interaction object comes within the device workspace. Similarly, the virtual workspace is changed in VE based on robot position. Stiffness discrimination task [4] [2] was conducted to analyze the haptic perception of the user while applying the proposed workspace extension algorithm. The experimental protocol is given in Table 1. The JND (Just Noticeable Difference) is calculated from the experimental data [4].

Table 1: Experimental design and protocol details.

Design parameters	Values
Stimulus	Two virtual walls with force feedback
Method	Constant stimuli
Measure	Stiffness JND
Analyze	Mean, standard deviation and variance
Task	Stiffness discrimination task
Stiffness levels	0.575 N/mm, 0.92 N/mm, 1.265 N/mm, 1.61 N/mm, 1.955 N/mm
No. of trials	50 trials for each case
No. of subjects	10
Stiffness interval	0.345 N/mm
Paradigm	Two-Alternative Forced Choice (2AFC)
Cases	Stationary (the robot was stationary) and moving (the robot was moving)

Results & Discussion:

Figure 2 shows an average psychometric curve [2] for stationary and robot moving conditions. The slope of the curve is the same for both the cases in the plot. Also, the (%) JND is almost the same for both the conditions of the experiment, as given in Figure 2. The subjects 7 and 9 have higher (%) JND for the moving case, and this could be because of the increased time taken by the subjects to reach the wall, which might have faded the haptic memory.

One way ANOVA test was performed on the experimental data between the robot moving and the stationary conditions. From this test, the observed p-value is 0.32, and this indicates that there is no statistically significant difference in the (%) JND between the two conditions of the experiment. This could prove that the proposed method of increasing the haptic device workspace is not significantly affecting the user stiffness perception in the VE.

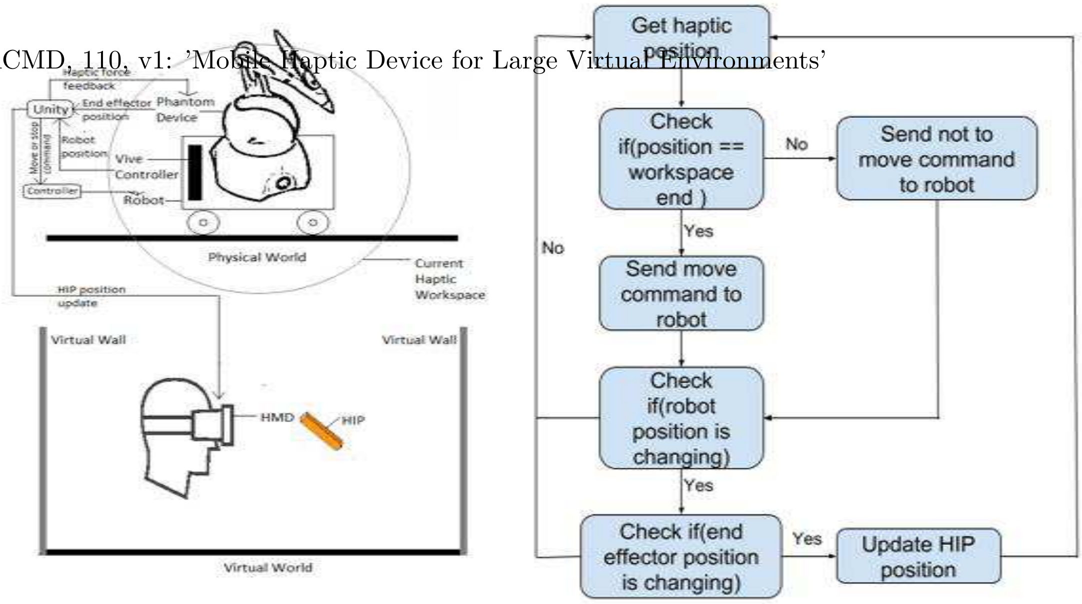

Figure 1: Device setup with the mobile robot (left) and HIP stands for Haptic Interaction Point; Position based workspace drift algorithm (right)

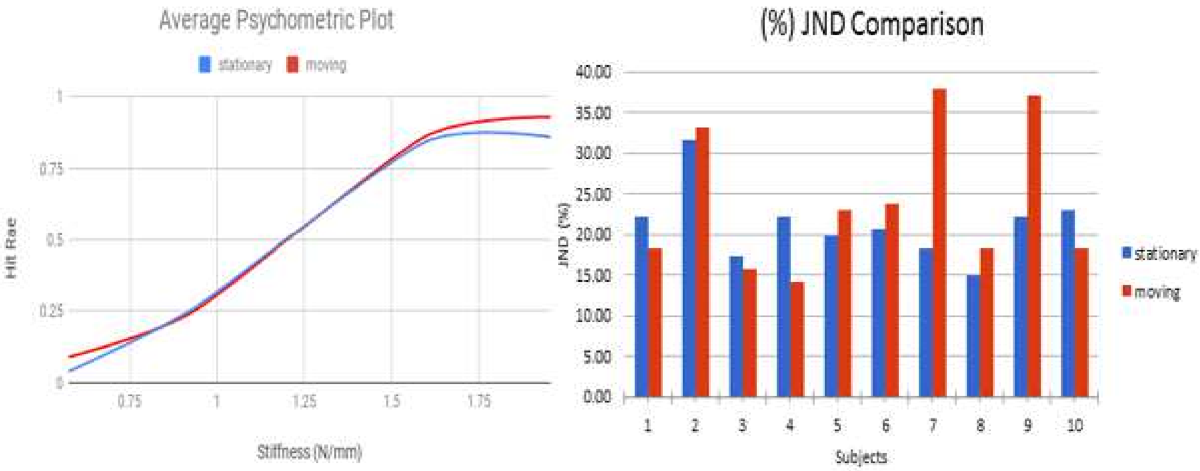

Figure 2: Average psychometric function (left) and (%)JND values for robot stationary and moving conditions across all subjects (right)

Conclusion:

The main aim of this work is to increase the haptic device workspace by using a mobile robot and the position based workspace drifting algorithm and checking whether the user perception is affected or not. The proposed method has been analyzed through psychophysical study and proven to be effective in increasing the workspace area of the haptic device without affecting the users' perception. Although current work is limited to a single axis, this methodology can extend to other axes and any grounded haptic devices.

References

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