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Mobilization and calibration of the HTC VIVE for virtual reality physical therapy

Sydney Hemphill, Alan Nguyen, Samuel T Rodriguez, Maria Menendez, Ellen Wang, Kiley Lawrence and Thomas J Caruso

Abstract

Aims: The HTC VIVE virtual reality (VR) system is a potential tool for collecting kinematic data during inpatient and outpatient physical therapy (PT). When validated against research-grade systems, the VIVE has a reported translational error between 1.7 mm–2.0 cm. Our purpose was to portabilize the VIVE for room to room PT and validate the motion tracking software.

Methods: The VIVE was configured on a mobile cart. To validate the motion tracking software, the VIVE sensors (motion tracker, controller, headset) were mounted on a rigid linear track and driven through 10, one-meter translations in the X, Y, and Z axes.

Results: The mean translational error for all three sensors was below 4.9 cm. While error is greater than that reported for research-grade systems, motion tracking software on the portable VIVE unit appears to be a valid means of tracking aggregate movement.

Conclusion: Some therapy may require more precise measurements, however, the advantages of portability and accessibility to patients may outweigh the limitation of reduced precision.

Keywords

Virtual reality, physical therapy, immersive technology, pediatrics, HTC VIVE

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Prevalent use of room-scale virtual reality (VR) for clinical interventions has traditionally been limited by cost and portability. Using a mobilized, room-scale VR system, opposed to a portable headset, allows for collection of kinematic data to potentially drive therapeutic interventions. Costing less than $1,000, the Stanford Chariot Program (chariot.stanford.edu) has mobilized a HTC VIVE VR system (VIVE) as a therapeutic adjunct for inpatient pediatric physical therapy while also gathering kinematic data through headset, arm, and leg sensors. Given the importance of early mobilization and physical therapy for inpatients, such data may be valuable for accelerating patient recovery.[1]

We studied the VIVE sensor sensitivity, which is reported to have high precision and low system latency, in order to demonstrate the clinical relevance of the VIVE kinetic sensor data. The orientation of its coordinate system is known to be tilted with respect to the ground plane, an error that can be minimized with appropriate calibration.[2] When compared to research-grade WorldViz PPT-X and InteriaCube, the maximum difference in reported height is 2 cm.[2] When validated against Liberty magnetic tracking system,

Department of Anesthesiology, Perioperative, and Pain Medicine, Lucile Packard Children's Hospital Stanford, Stanford University, Stanford, CA, USA

Corresponding author:
Thomas J Caruso, 300 Pasteur Drive, H3580, Stanford, CA 94305, USA.
Email: tjcaruso@stanford.edu

a mean translational error of 1.7 +/− 0.4 mm and 2.0 +/− 0.8 mm was reported for the tracker and controller, respectively.[3] However, these validation data were completed on room scale VIVE configurations. The purpose of this brief report is to assemble the VIVE as a portable unit and report sensor validation on a portable VIVE with motion tracking software.

Narrative

Mobilization of the VIVE

In order to mobilize the VIVE, the system was fitted onto a battery-powered computer cart (Model J-LUCI-VINL-0A, Enovate Medical) (Figure 1(a)). The cart houses an ASUS Republic of Gaming laptop (Model G752VS, ASUS) on which the clinician can configure, customize and monitor the VR session. The laptop display is mirrored on a 24-inch monitor with Vesa mount (Model E242, HP) via HDMI, which allows the care team or family to see what the user is experiencing within the VR headset. The VIVE lighthouse sensors were secured onto the computer cart with an adjustable articulating arm (Model B06VYCVVVJ, Pangshi) (1B). Two holes, each 3 cm in diameter (1 C), were drilled into the back of the computer cart to thread USB charging cables into the cart's two drawers, where the VIVE controllers and motion trackers are stored (1 D). The drawer is secured by a number lock (Model 1000SG, KitLock). A USB dongle was connected to the laptop to house the motion tracker USBs (1E). A power strip was secured above the drawers to house the VIVE and additional USB chargers. A plastic platform with a 2 × 4 cm bore was secured onto the computer cart in order to lock the VIVE Headset in place while not in use (1 F). This configuration allows the VIVE system to function as a mobile unit for room-to-room patient care.

Monitor considerations

When VR is used for hospitalized patients undergoing physical therapy, physiologic monitoring can be useful, and in many cases unavoidable as monitors are present

Figure 1. HTC VIVE portable station configuration. (a) Battery-powered computer cart (Model J-LUCI-VINL-0A, Enovate Medical), (b) adjustable articulating arm (Model B06VYCVVVJ, Pangshi), (c) bore holes for charging cables, (d) charging and storage drawer, (e) USB dongle + motion tracker USBs, (f) headset locking platform.

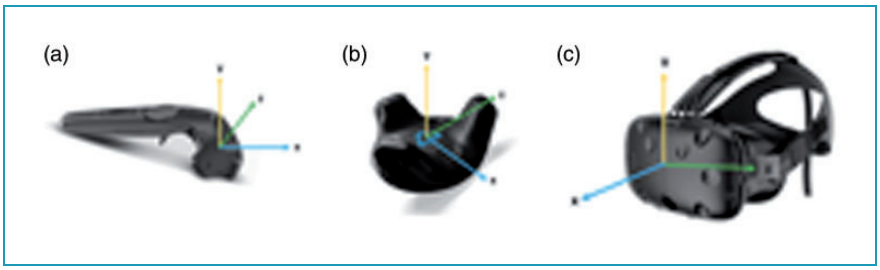

Figure 2. VIVE sensors. (a) VIVE controller, (b) VIVE motion tracker, (c) VIVE headset.

for other clinical purposes. When the VIVE system was used in conjunction with a MasimoSET pulse oximeter, there was interference with the pulse oximetry signal. The MasimoSET pulse oximeter determines SpO_2 by measuring transmitted red and infrared (IR) photoplethysmographic signals, followed by a series of calculations and adaptive filtering.[4] The VIVE base stations emit periodic IR pulses and sweeps that are able to track the controllers and headset in space via embedded photoiodes; these base stations have the ability to affect nearby IR sensors.[5,6] When using the VIVE and MasimoSET pulse oximeter concurrently, this IR interference can be eliminated by applying a dressing around the pulse oximeter sensor to block the IR signal from the VIVE Base Station, thereby allowing both systems to function independently.

Calibration and motion tracking validation

The VIVE was initially calibrated according to the user's manual in order to test the motion tracking software Movement™, which was developed by Mighty Immersion (New York City, NY) for the Stanford Chariot Program. The software tracks each focus point (motion tracker, controller, headset) in space via the VIVE lighthouse sensors using three-dimensional (3 D) coordinates, measured in centimeters (Figure 2). The 3 D coordinates of each focus point are recorded within each frame (90 frames/second), and the movement (current location – previous location) is added to the total measured movement for that focus point. Movement data for each focus point is summed and graphed in real time and archived in the Movement application.

In order to validate the motion tracking software, each component of the VIVE system (motion tracker, controller, headset) was mounted on a rigid linear track and driven through ten, one-meter translations in the X, Y, and Z axes. The mobile VIVE cart was positioned so that both lighthouse sensors were aimed directly at the track at a distance of 1.5 m. This configuration can be replicated in patient rooms and allows for an area of play comparable to the VIVE recommended room scale dimensions (2 m × 1.5 m).[6] Unlike room scale VR, the calibration of movement using this mobile unit required the sensors to be placed closer together than typically and at the level of the mobile unit, which would be placed at the foot of a patient's bed. Both sensors were pitched downwards approximately 30 degrees in accordance with manufacture recommendations.[6] Movement™ motion tracking software was run simultaneously, at a sampling rate of 90 Hz via the lighthouse sensors. Translational error was determined by subtracting the distance measured by the software from the length of the one meter track. Because the VIVE software recorded both higher and lower values than the length of the track, the absolute value of the difference was used.

Findings

The mean translational error for the motion tracker was 2.43 +/− 1.57 cm. Mean translational error for the controller and headset was 3.63 +/− 1.27 cm and 2.10 +/− 0.61 cm respectively.

Discussion

We aimed to configure the VIVE system as a mobile unit for room-to-room therapy and to quantify the translational error of the motion tracking software for three VIVE sensors (motion tracker, controller, headset). Our purpose was to validate the motion tracking software on the mobile configuration to assess accuracy for the collection of kinematic data.

The translational error measurements between the software and physical distance traveled for the three VIVE sensors is greater than that reported for research-grade motion capture systems. Although not as precise as room scale configurations, the mean translational errors were all below 4.9 cm, which is likely clinically irrelevant as many physical therapy outcome measures are on the scale of meters, such as the 6 minute walk test with a minimum clinically important difference of 33 m.[7] Additionally, the majority of physical therapy exercises in the inpatient settings that this mobile unit was designed to serve are focused on gross

rehabilitation as opposed to extremely fine movements. While some physical therapy may require greater precision when tracking more subtle movements, the advantages of portability and accessibility to patients may outweigh the limitation of reduced precision in appropriate clinical scenarios.

Potential future applications include integrating this mobile unit into other clinical settings and using the kinematic data collection software to help guide and monitor outcomes such as physical therapy progress.

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ORCID iDs: Sydney Hemphill https://orcid.org/0000-0003-2893-9485
Ellen Wang https://orcid.org/0000-0002-9151-938X

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