[DEMO] Comprehensive Workspace Calibration for Visuo-Haptic Augmented Reality

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(a) (b) (c)

Figure 1: Visuo-haptic augmented reality system with a PHANToM haptic device. Virtual stylus overlaid (a) with joint angle calibration only (b) with our additional gimbal angle calibration. (c) System diagram for workspace calibration demonstration with additional AR guides.

ABSTRACT

Visuo-haptic augmented reality systems enable users to see and touch digital information that is embedded in the real world. Precise colocation of computer graphics and the haptic stylus is necessary to provide a realistic user experience. PHANToM haptic devices are often used in such systems to provide haptic feedback. They consist of two interlinked joints, whose angles define the position of the haptic stylus and three sensors at the gimbal to sense its orientation. Previous work has focused on a calibration procedures that align the haptic workspace within a global reference coordinate system and an algorithms that compensate the non-linear position error, which is caused by inaccuracies in the joint angle sensors.

In our science and technology paper "Comprehensive Workspace Calibration for Visuo-Haptic Augmented Reality" [1], we present an improved workspace calibration that additionally compensates for errors in the gimbal sensors. This enables us to also align the orientation of the haptic stylus with high precision. To reduce the required time for calibration and to increase the sampling coverage, we utilize time-delay estimation to temporally align external sensor readings. This enables users to continuously move the haptic stylus during the calibration process, as opposed to commonly used point and hold processes.

This demonstration showcases the complete workspace calibration procedure as described in our paper including a mixed reality demo scenario, that allows users to experience the calibrated workspace. Additionally, we demonstrate an early stage of our proposed future work in improved user guidance during the calibration procedure using visual guides.

Index Terms: H.5.1. [Information Interfaces and Presentation]: Multimedia Information Systems—[Artificial, augmented and virtual realities]; H.5.2. [Information Interfaces and Presentation]: User Interfaces—[Haptic I/O];

1 INTRODUCTION

Researchers have started to combine augmented reality (AR) and haptic interaction to enable users to see and touch digital information that is embedded in the real world. Precisely calibrating all components of a visuo-haptic augmented reality (VHAR) system: external trackers, cameras, haptic devices, and the spatial relations between them is essential to provide a realistic user experience. Specifically, the integration of haptic devices is not trivial. First, the haptic feedback needs to be precisely colocated with the visual augmentations and second, the position and orientation of the haptic stylus need to be known in order to augment it or to hide it.

Haptic devices for providing kinesthetic feedback are usually based on one of the two concepts: stylus- and grip-based devices for tool interaction and string-based systems for grasp tasks. Massie and Salisbury [7] developed the widely used stylus-based PHANToM haptic device, which consists of two interlinked joints. The angles of these joints define the position of the haptic stylus, commonly called haptic interface point (HIP), and and three sensors at the gimbal sense its orientation.

Various solutions have been proposed to integrate haptic devices into AR environments [11, 6, 2], but all of them focused on the calibration of the HIP position, which is very important to colocate linear force feedback. However, in order to precisely overlay graphics onto the stylus it is essential that its orientation is reported correctly too (see Figure 1a). Corrected stylus orientations are also important for VHAR applications with torque actuators, so that haptic torque feedback is precisely colocated as well.

2 RELATED WORK

The most important previous research is the work by Harders et al. [2]. They presented a calibration procedure for VHAR workspaces and an algorithm to compensate the non-linear distortion of position measurements of PHANToM haptic devices for the complete workspace. They used an external tracker and attached a tracking target rigidly to the haptic stylus to perform an open-loop calibration [3].

Huber et al. [9] presented Ubitrack, an ubiquitous tracking and sensor fusion framework, which forms the basis of our implementation. Spatial relationship patterns [8] are used to define the spatial relations between entities in a system. Ubitrack implements an asynchronous dataflow network and provides components for calibration, persistence, and device drivers.

We determine the time-delay between our sensors using an algorithm presented by Huber et al. [5].

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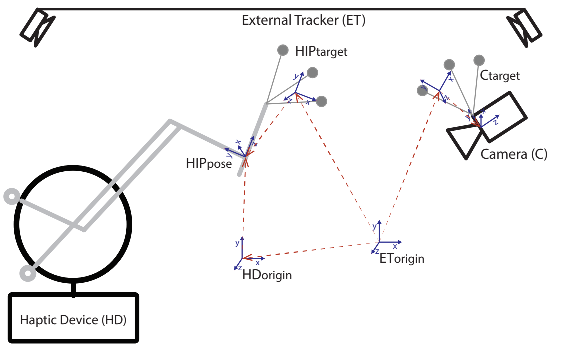


Figure 2: Our setup for for VHAR workspace calibration and its spatial relations.

Our work extends Harders and colleagues' method to all six device sensors, resulting in a precise 6DOF alignment of the haptic stylus and visual overlays (see Figures 1a, 1b).

3 DESCRIPTION OF DEMO APPLICATION

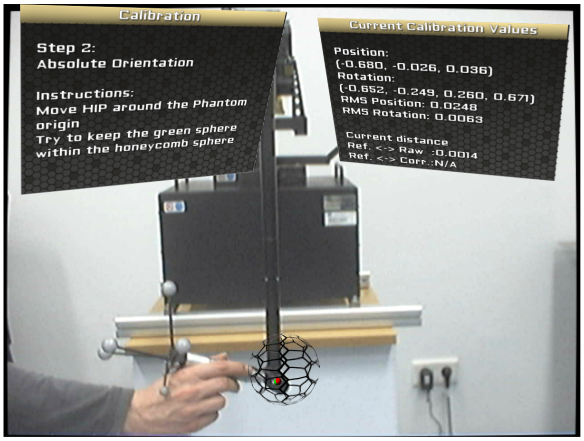
In this demonstration users will be able to perform a complete VHAR workspace calibration. After successful completion, they can experience a VHAR scenario to evaluate the quality of the calibration. Visual guides help novice users to replicate the required movements during calibration. These guides are presented using a tracked head-mounted display (HMD). An overview of the proposed setup is shown in Figure 1c.

Users are required to perform a sequence of steps in a predefined order in order to complete a workspace calibration. During each step spatial relations are determined (see Figure 2) or sensor errors are corrected. Users get visual feedback about the calibration result during each calibration step on a monitor or through AR elements and status panels while wearing the HMD (see Figure 3). The complete sequence of steps is shown in Table 1.

Table 1: Overview of the calibration procedure

Step	Description	Relation
Time Delay Estimation	Tooltip [10]	$HIP_{target} - HIP_{pose}$
	Absolute Orientation [4]	$ET_{origin} - HD_{origin}$
	Time Delay Estimation [5]	$\Delta t(HD - ET)$
Position Calibration	Joint-Angle Calibration [2]	HIP_{pose}
	Absolute Orientation [4]	$ET_{origin} - HD_{origin}$
	Joint-Angle Calibration [2]	HIP_{pose}
Orientation Calibration	Orientation Reference	$HIP_{target} - HIP_{pose}$
	Gimbal-Angle Calibration	HIP_{pose}

The demo is mainly controlled through a tracked Wii-controller. Using the controller, the status panels can be freely moved around in the workspace. The demo offers a calibration and an inspection mode. In the calibration mode, AR guides are visualized to guide the user through the calibration process. Each calibration step has its own visualization. For example figures 3 shows the first, initial, absolute orientation calibration step. To keep the error in this calibration step small, the user has to gather measurements near to the origin of the Phantom device. Otherwise the distorted workspace of the Phantom will have too much impact on the calibration. To guide the user, a honeycomb structured sphere is visualized in the origin of the Phantom workspace. The user should try to keep the haptic interaction point within the sphere.



Step 2:
Absolute Orientation

Instructions:
Move HIP around the Phantom origin
Try to keep the green sphere within the honeycomb sphere

Position:
(-0.680, -0.026, 0.036)
Rotation:
(-0.652, -0.249, 0.260, 0.671)
RMS Position: 0.0248
RMS Rotation: 0.0063

Current distance
Ref. <-> Raw :0.0014
Ref. <-> Corr.:N/A

Figure 3: Demo Application, Step 2:, Absolute Orientation

The inspection mode offers different visualizations to inspect the input data used for the current calibration step and the current workspace distortion. Again, depending on the current calibration step, different visualizations are available. The current workspace distortion, for example, can be inspected using the tracked controller. On the controller, a plane is attached that visualizes a slice of the workspace distortion as a heat map.

For details on the calibration algorithm and procedure we refer to our publication [1].

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