A Procedure for Accurate Calibration of a Tabletop Haploscope AR Environment

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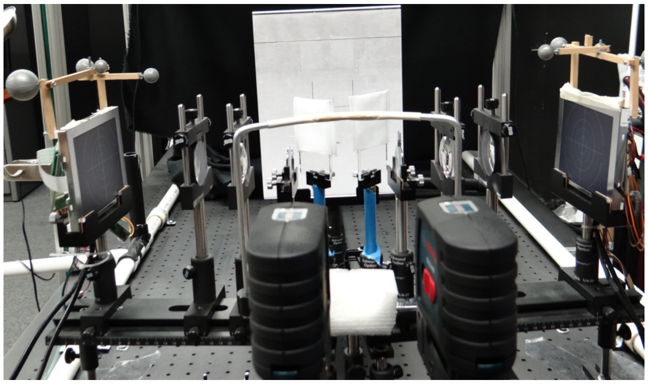

Figure 1: AR Haploscope System with Calibration Target

Figure 2: Laser Level Calibration System and Calibration Target

Index Terms: Augmented Reality, Calibration, Depth Perception.

1 Introduction

In previous papers, a novel haploscope-based AR environment was implemented [1, 3]. In that system, a participant looks through a set of reflective lenses onto a real-world environment. However, at the same time, there are monitors to the side displaying a virtual object. This object is reflected onto the lenses and is thus, from the viewpoint of the participant, overlaid onto the real environment. In Hua [1], some initial work was done designing a calibration procedure for this haploscope-based AR environment. The current work seeks to modify and expand Hua's original calibration procedure to make it both more effective and more efficient. As part of developing this new calibration procedure, this paper examines potential sources of error and recommends processes and steps for reducing or eliminating these potential error sources.

2 Calibration Procedures

To properly calibrate the haploscope system, which is illustrated in Figures 1 and 6, each source of potential calibration error must be examined and, as much as possible, reduced. By investigating and neutralizing each potential error source, we aim to allow an observer to view a virtual object with the same optical and perceptual properties as a real object at the same location. If perceptual tests with a virtual object give results that are similar enough to those same tests performed with a real object, then we can conclude that the calibration procedure is effective in ensuring that the haploscope system is accurate. In creating this procedure, we will have developed a methodology which can be applied to any future and current haploscope systems to ensure maximum accuracy.

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To ensure accurate calibration, there are a few miscellaneous things that were investigated. Before any significant calibration could properly commence, the haploscope table had to be balanced with respect to gravity, the position of the lenses had to be checked, and the tracking system had to be appropriately set up, among others. After these initial steps, calibration began in earnest.

As seen in Figures 2, 3, and 4, the first proper step in the proposed calibration procedure involves using a pair of laser levels mounted to an optical ruler, which is, in turn, mounted on a tripod. This optical ruler is placed some distance from the haploscope table, such that the ruler is parallel to the table. Then, a calibration target is attached to the table, with the center of the target in the same vertical position as the center of the table. In the final step, the laser levels are turned on, centered across from the lenses that the user will look through, and aimed at the larger lines on the target. To determine if both laser levels are appropriately centered, the target is moved some distance away; if the position of both vertical laser beams does not change, then they are both positioned appropriately. Once this has been done, the LCD screens which display the virtual image are adjusted so that the center of each screen corresponds with the origin of the appropriate laser level.

Next, to provide a confirmation that everything has been properly calibrated and to ensure that the tracking system is working as it should, we use a verged calibration scheme, shown in Figure 3. In this scheme, everything is setup as in the previous step. However, the calibration target is moved to 38 cm away from the participants' normal viewing location. Both laser levels are moved away from each other by $Y/2$ cm, where Y is a value that can be calculated using the formula included in Figure 3. The tabletop haploscope is then set up to display a target at 38 cm. Once this has been completed, both screens are examined; if the center of both screens still corresponds to the origin of the appropriate laser level, then the system has been fully calibrated and is operating correctly. If desired, this final step can be repeated for a different target distance, to provide additional confirmation that everything is working correctly.

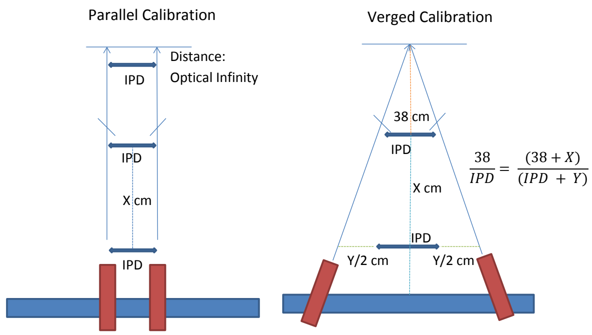

Figure 3: Parallel Calibration and Verged Calibration; X represents the distance between the optical ruler and the user's viewing location and Y is the calculated value.

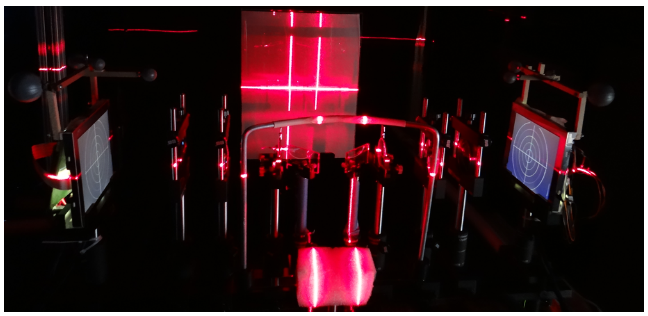

Figure 4: Laser level calibration in action

3 Other Potential Error Sources

There are a few other potential error sources that should be mentioned (and that could, potentially, disrupt either the calibration steps mentioned previously or the experiment itself). Some of these potential error sources include: distortion and diffraction in any of the optical members, the effect of brightness on perceived distance, and possible dipvergence effects. Some of these error sources, like distortion and diffraction, can be reduced through careful material selection and treatment, but are difficult to eliminate entirely from a haploscope system based on optical glass. Others, such as brightness, can have a biasing effect that is difficult to discern without significant experimentation [3]. Finally, this calibration procedure deals with dipvergence by using laser levels with both a horizontal and vertical leveling component (as seen in Figure 4); this ensures that, when the screens are calibrated, they are in the correct horizontal and vertical position, thus greatly reducing dipvergence effects.

Another important source of potential error is in the inputs to the haploscope system, namely, a participant's interpupillary distance (IPD). If a participant's IPD is not veridical, the results from that participant could be severely disrupted; Hua [2] found that, as the focal distance of a viewing object changes, the user IPD also changes by a total magnitude of 4.5 mm, on average. Notably, then, it is important to find accurate measurements for a user's IPD at relevant distances. However, many experiments call for IPD values at distances that cannot be measured by standard IPD-measuring devices. As seen in Figure 5, standard IPD-measuring devices are not very precise; notably, readings taken with such a device can only be as precise as the units the device uses. To counter-act these problems, we take several different measurements of a user's IPD at different distances. Then, based on this data, we plot the results and calculate a logarithmic function to approximate a user's IPD at any given distance. This methodology not only allows us to calculate a participant's IPD at any distance, it allows us to determine a participant's IPD more precisely than direct measurement can.

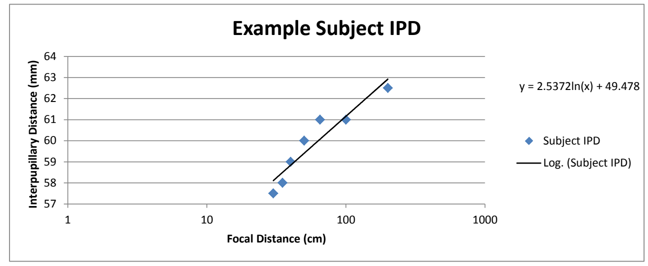

Figure 5: Example IPD plot; note that the x-axis is in log scale.

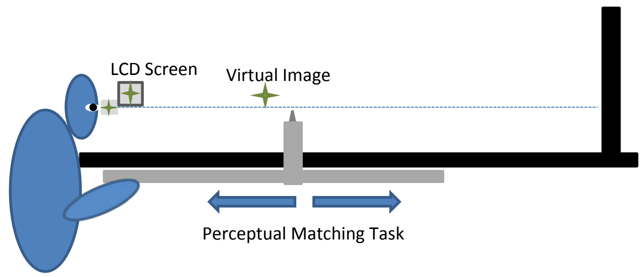

Figure 6: Example Haploscope Experimental Use; this example represents a participant presented with the perceptual matching task of aligning a virtual image with a real-world pointer.

4 Results

At this point, this calibration procedure has not yet been fully tested. To determine the calibration procedure's full effectiveness, we plan on using cameras to compare the locations of a virtual and real object, to determine if the virtual display is indeed veridical, as performed by Hua [1]. We also plan to test this procedure by conducting additional perceptual experiments like those performed by Hua [1] and Singh [3]. The results from these experiments would measure the effectiveness of these calibration procedures at eliminating error. From there, the combination of the haploscope system and the accurate calibration procedure will enable the rapid testing of various optical properties, allowing the effect of these properties on users' perception of various AR environments to be rigorously tested and defined.

Acknowledgements

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References

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