Baseline SPAAM Calibration Accuracy and Precision in the Absence of Human Postural Sway Error

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ABSTRACT

We conducted an experiment in an attempt to generate baseline accuracy and precision values for optical see-through (OST) head mounted display (HMD) calibration without the inclusion of human postural sway error. This preliminary work will act as a control condition for future studies into postural error reduction. An experimental apparatus was constructed to allow performance of a SPAAM calibration using 25 alignments taken using one of three distance distribution patterns: static, sequential, and magic square. The accuracy of the calibrations were determined by calculating the extrinsic X, Y, Z translation values from the resulting projection matrix. The standard deviation for each translation component was also calculated. The results show that the magic square distribution resulted in the most accurate parameter estimation and also resulted in the smallest standard deviation for each extrinsic translation component.

Keywords: Augmented reality, calibration, SPAAM, alignment.

1 INTRODUCTION

Accurate calibration is a critical facet of any AR application. OST AR calibration has inherent inaccuracy since it relies on user feedback to perform the adjustment procedures as well as quantify the resulting quality of the calibration [4]. The single point active alignment method (SPAAM) calibration technique, [5], is a common method for performing calibration of an OST AR system utilizing alignments between on screen reticles and a target marker in the world. The accuracy of this calibration method has been shown to improve when greater depth variance between alignment points is used [1, 2] and also by minimalizing user input error [3]. This abstract presents the preliminary results of an experiment to generate baseline accuracy and precision estimates for SPAAM calibration by removing any contribution from human error induced by involuntary postural sway. These results will form the basis of a control condition for future studies investigating methods of reducing human error in OST calibration. Accuracy and precision estimates were calculated for calibrations performed using one of three alignment distance distribution patterns. (1) *Static*: All alignments were made from a single stationary position 3m from the target marker. (2) *Sequential*: The distance to the target marker was increased incrementally by .1m after each alignment, starting at a distance of 1.28m and extending to a maximum of 3.78m. (3) *Magic Square*: Adapted from [1], a 5×5 Magic Square was used to map the distances used for the sequential pattern to alignment points, creating greater variation in depth of the alignments.

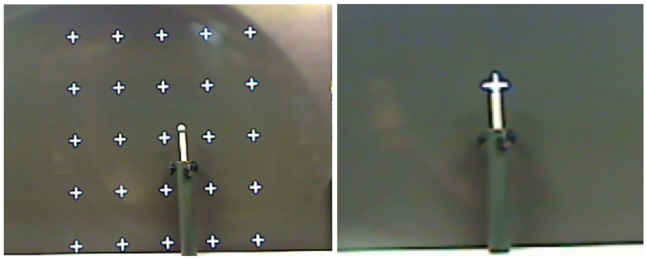

Figure 1: (Left) View through the HMD of the complete 5x5 grid of alignment points. (Right) View of an alignment between a single on screen reticle and the target marker.

2 EXPERIMENTAL DESIGN

A target marker, rigidly fixed to one location, was aligned with a set of 25 on screen reticles, in the form of crosses. The reticles were arranged in a 5×5 2-D array on the display, with each reticle having a width and height of 40 pixels and a line thickness of 3 pixels. The grid of reticles was centered on the display with equal distance between crosses within a row and column. Figure 1 shows the view through the HMD of the complete reticle grid, along with an alignment between one cross and the target marker. 5 repititions, using all 25 alignment markers were conducted for each of the three distance distribution patterns for a total of 15 trials.

2.1 Hardware

A Logitech QuickCam Pro 9000 camera was mounted inside of an nVisor ST50 optical see-through head mounted display with 40° × 32° field of view. Video from the camera was recorded at 30 frames per second with a resolution of 800×600, and a resolution of 1280×1024 was used in the HMD. Although the display is binocular, the camera was positioned behind the left eye piece for each trial. The camera was affixed to a miniature ball head joint to allow for minor adjustments in yaw, pitch, and roll. The camera-head assembly was mounted to an adjustable height optical post holder set on a pair of optical rails allowing three dimensional translation adjustment of the camera with mm accuracy. The HMD and optical rails used in the camera mounting were themselves affixed to a rigid frame fastened to a Manfrotto 405 Pro Digital Geared Head. The geared head facilitated the adjustment of the the entire HMD and camera system in yaw, pitch, and roll with sub angle precision. Figure 2 providesa detailed views of the complete experimental apparatus. The on screen reticles were rendered by a platform consisting of a 3.9 GHz Intel Core i7 processor with 32 GB of RAM running Windows 7 and dual NVIDIA GeForce GTX 680 graphics cards. Tracking of the HMD assembly was performed using an Intersense IS-900 acoustic tracking system with a positional resolution of .75mm and angular resolution of 0.05°, according to the equipment manufacturer. The head tracking unit for the IS-900 was affixed to the top front of the HMD such that the origin of the HMD coordinate frame is between the two eye pieces..

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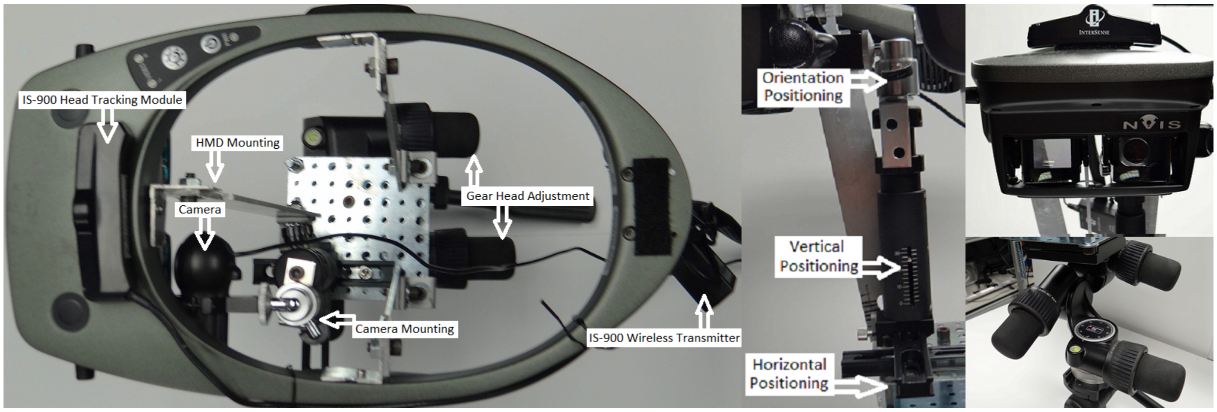

Figure 2: Views of the experimental apparatus. (Left) the HMD and camera assembly mounted to the gear head. (Middle) Closeup view of the camera assembly. Optical rails and post holder allow translational movement and the miniature ball head allows for angular adjustment. (Top Right) View of the camera through the front of the display. (Bottom Right) The gear head used to adjust the entire apparatus during alignments.

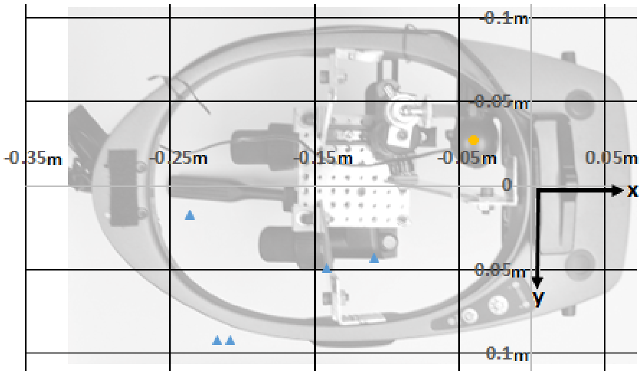

Figure 3: Plot of the X and Y extrinsic parameters for each calibration using the magic square distance distribution. The triangles represent the locations of the values for each of the 5 calibrations performed, and the circular point represents the exact location of the camera within the HMD coordinate frame.

2.2 Procedure

The experimental procedure was kept constant for each of the 15 trials, 5 for each of the three distance distributions. Prior to performing the calibrations, the vertical and horizontal position as well as the angle of the camera within the HMD was adjusted to center the camera about the exit pupil and correct any angular offsets with the display. Using the tracker readings, the testing apparatus was moved to the appropriate distance according to the distribution pattern used. Alignments between the on screen reticles and target marker were performed starting with the lower left cross and proceeding in row major order through the entire array for a total of 25 screen to target alignments. Only one cross was visible at a time, and the camera feed was used to guide adjustments to the gear head to perform the alignment.

3 EXPERIMENTAL RESULTS

The accuracy of each calibration was estimated by calculating the extrinsic eye location parameters from the resulting projection matrix using the method described in [1]. The mean, as well as the standard deviation, for the X, Y, and Z extrinsic values were calculated for each distance distribution and are provided in Table 1. The X, Y, and Z estimates for the Magic Square distribution were the most accurate. Figure 3 shows the X and Y magic square estimates within the HMD cooridnate frame. The estimates for the sequential and static distributions are otuside the bounds of the figure.

	Magic Square	Sequential	Static
X	-0.18258m (0.04725)	1.90808m (0.296068)	2.3567m (0.353345)
Y	0.05888 (0.016)	-0.30254m (0.064349)	-1.24752m (0.502426)
Z	0.0858m (0.0181)	-0.1572m (0.090506	0.40974m (0.821101)

Table 1: The mean (and standard deviation) of the X, Y, and Z extrinsic values within the HMD coordinate frame.

4 CONCLUSIONS

The preliminary results presented support the claim that a more depth variant alignment pattern produces more accurate and precise results than linear or static distributions. Further work will involve producing a larger number of calibrations for the 5×5 alignment grid, as well as for grids of 6×6 and 7×7 alignment points. The accuracy and standard deviation from those results will serve as a control measure for future studies examining ways to reduce human postural error during an OST HMD calibration.

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