Measuring ARToolKit Accuracy in Long Distance Tracking Experiments

Pierre Malbezin, Wayne Piekarski and Bruce H. Thomas
Wearable Computer Laboratory
School of Computer and Information Science
University of South Australia
Mawson Lakes, SA, 5095, Australia
pierre@tinmith.net, {wayne, thomas}@cs.unisa.edu.au

Abstract

This paper presents the results from an experiment which was performed to test the ARToolKit and the accuracy of its tracking over large distances of 1 to 3 metres. We used ARToolKit to extract the position of a camera pointed at a fiducial marker, and compared these values to physical measurements to quantify the accuracy of the tracking. The results indicate that the error in position increases with the distance from the target, and that the error also varies in X and Y in phase opposition when orbiting around the pattern. We suggest further experiments to perform and the creation of filters which could reduce at least 75% of the errors detected in this initial experiment.

1. Introduction

This paper presents the results of some experiments we have been performing which are designed to measure the accuracy of the ARToolKit [1] tracking software. ARToolKit is commonly used in augmented reality (AR) applications to detect fiducial markers and overlay a 3D object at this position, usually within arm's reach. In these applications, the distance between the user and the target is often quite small (less than one metre), and so many errors are not noticeable except at larger distances.

In some cases, it may be desired to use ARToolKit in larger scale environments, but there has not been much previous work in this area, and so we decided to test its accuracy. At large, room sized distances, accuracy seems to depend on the angle that the target is at, with either the corner or the side facing the camera. The aim of the experiment described in this paper is to test ARToolKit's positioning accuracy for distances between 1 and 3 metres, and at different angles. We first explain how the experiment was performed, and then analyse the results.

2. Experimental setup

For this experiment, we fixed a fiducial marker on the floor of a large empty room, and drew four circles centred on the target at a distance of 1, 1.5, 2, and 2.5 metres. At distances of 3m and higher, the camera had difficulties detecting the target and so 2.5m was set as the upper limit (see figure 3).

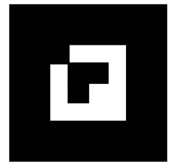

Figure 1 – Asymmetrical 20 cm x 20 cm pattern used for the experiment

For the fiducial marker pattern, we wanted to orbit around it with the camera and calculate position and orientation, so an asymmetrical pattern (see figure 1) was created. The marker was 20 cm x 20 cm and glued onto a flat rigid surface to ensure that it was held as straight as possible.

The next step was to fix the marker down into the middle of a solid rectangular surface. This surface was then placed down on the floor of the room, and it was estimated that the error in this position was a maximum of 2 mm, contributing an error of 0.3 degrees. Once the board was placed down onto the floor, we create straight lines in the direction of the X and Y axes, using the perpendicular bisector method on the corners of the board. These axes allow us to measure the position of the camera relative to the marker, and the error contributed by the placement of these axes was estimated at 0.2 degrees.

To draw the circles around the fiducial marker at the centre, we used a 3 metre long piece of string pulled tight, which could be rotated about the centre. Four marks on the string at 1m, 1.5m, 2m, and 2.5m indicated the points for the camera to be placed at. The angles that the camera was placed at were at about every 15 degrees. The positions of the camera were calculated by projecting onto the axis, and this process contributes an error of about 5mm.

The camera used for the experiment is a 1394 Firewire

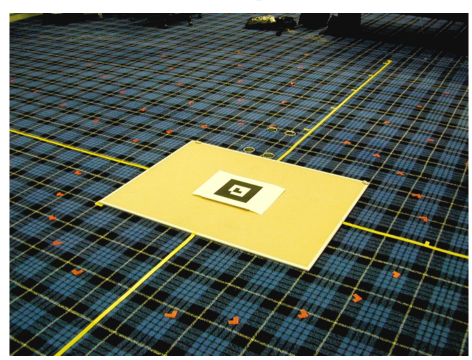

Figure 2 – View of the experimental setup

In ART02, 1st International Augmented Reality Toolkit Workshop
September 29, 2002 - Darmstadt, Germany - Copyright (C) 2002 IEEE
Please visit http://www.tinmith.net for more information

Pyro WebCam, which allows most of the settings to be altered in software (camera parameters show in Figure 7). The camera was fixed onto a tripod to make it more stable and able to be measured accurately, and was placed at a height of 1.34m. A plumb line stretched beneath the tripod to the ground points to where the camera stands on the floor so that we can get as accurate placement as possible. The camera is aimed down toward the pattern and the image is centred on the pattern to avoid image distortion problems.

The testing program we developed for the experiment uses the ARToolKit functions to calculate the position of the camera relative to the target. For each position of the camera, the program calculates the matrix 1000 times and averages the values to remove any noise in the measurements.

3. Experiment results and analysis

For the accuracy of the measurements, we noticed that the Y position is always more accurate than the X position, as shown in figure 4. We believe it might be that the X axis created at the start of the experiment may have had a larger error than the Y axis.

For each of the points processed, it appears that the radial distance estimated by ARToolKit is always a larger value than the real measurement, and figure 5 shows the estimated and measured circles with this demonstrated.

In figure 4, we can clearly see that the error increases with distance, from 9% to 18% for Y and from 6% to 12% for X. It might be possible to correct for this error by adding a filter which would estimate the distance to the target based on the values from ARToolkit. As a first step for this calibration, a linear function could be tried to see if it helps improve the accuracy. To extend this filter to other cameras or settings, it would then be enough to measure the error at 1m and 2.5m and then interpolate the values in between.

Finally, another result from the experiment is that the accuracy of the X and Y values fluctuates with the angle that the camera is at to the target, as shown in figure 6. The results show that the X values are more accurate around 90^o and 270^o, while the Y values are more accurate around 0^o and 180^o, which is the opposite of the X values. This may come from the pattern design, but for now we are not sure of the cause of this phenomenon.

4. Conclusion

In this paper, we described an experiment that was performed to measure the positioning accuracy of ARToolKit at distances between 1m and 2.5m. It appears that the error in the X and Y values increases with the distance from the target. Also, the accuracy of X and Y appears to change with the angle from the target, although at opposite phases.

Using these results, it should be possible to use a correction filter that would detect the angle and distance, and then correct the X and Y values up to 75% of what was measured. Also, to better understand the problems being investigated in this paper, we think it would be interesting to repeat the experiment but with the following changes: using different camera models and lenses; doing the same tests at other distances; testing the proposed linear correction method; and using a different marker pattern. While the results in this paper are preliminary, it gives a starting point for future research into quantifying the accuracy of the ARToolKit.

Distance (m)	1	1.5	2	2.5
Error (mm)	± 14	± 18	± 22	± 27

Figure 3 - Maximum error values for the four distances

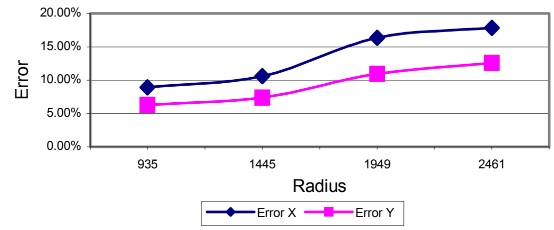

Figure 4 – X and Y mean error values for the four radius values

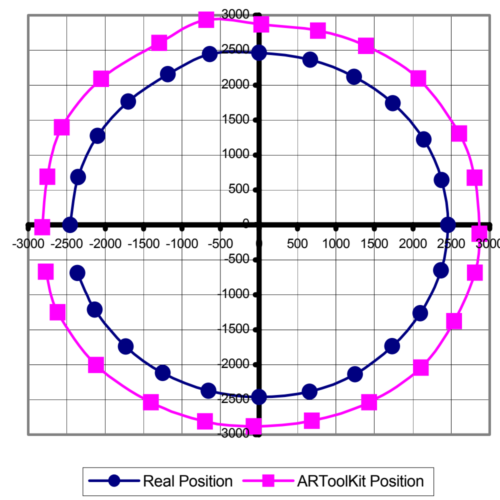

Figure 5 – ARToolKit radius estimates are always larger than actual physical measurements (units are millimetres)

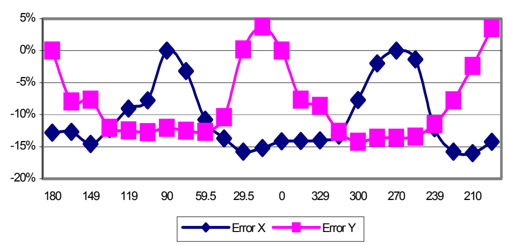

Figure 6 – X and Y error values change with the angle (units are degrees)

```
Size   = (640, 480)      | 750.51    0.00 320.00  0.00 |
Centre = (320, 240)      |   0.00  722.98 240.00  0.00 |
Focal  = 60.900000       |   0.00    0.00   1.00  0.00 |
Size   = 1.036854        |   0.00    0.00   0.00  1.00 |
```

Figure 7 – ARToolkit parameters for the 1394 Pyro camera, straightened to correct for inaccuracies in the calibration process

5. References

[1] Kato, H. and Billinghurst, M. Marker Tracking and HMD Calibration for a Video-based Augmented Reality Conferencing System. In *2nd Int'l Workshop on Augmented Reality,* pp 85-94, San Francisco, Ca, Oct 1999.