# Evaluation of the ShapeTape Tracker for Wearable, Mobile Interaction

Yohan Baillot, Joshua J. Eliason, Greg S. Schmidt, J. Edward Swan II,
Dennis Brown, Simon Julier, Mark A. Livingston, Lawrence Rosenblum

Virtual Reality Laboratory, Naval Research Laboratory, Washington D.C.

## Abstract

*In this paper we describe two engineering experiments designed to evaluate the effectiveness of Measurand's ShapeTape for wearable, mobile interaction. Our initial results suggest that the ShapeTape is not appropriate for interactions which require a high degree of accuracy. However, ShapeTape is capable of reproducing the qualitative motion the user is performing and thus could be used to support 3D gesture-based interaction.*

## 1. Introduction

The advent of wearable computing has created the need for new human–to–computer interaction paradigms and interface devices. While keyboards and mice are sufficient for desktop computers, they are not appropriate for wearable computers where more natural 3D interactions are required. We postulate that a successful hand tracking system for a wearable, mobile system needs to be body-mounted, accurate enough to support the desired interactions, is easy to configure and calibrate, and does not interfere with the user's normal body interactions. Potential technologies include computer vision [1], ultrasonics [2] and Measurand Corporation's ShapeTape [3]. ShapeTape is a thin flexible ribbon composed of bend and twist sensors which measure the attitude of the tape at various positions along its length. Given the fact that it is a small, lightweight, low-powered technology which does not rely on extensive signal processing and does not restrict the user's movements, ShapeTape appears to be well-suited for the problem of 3D interaction and gesture recognition. To assess its suitability, we integrated it into the Battlefield Augmented Reality System (BARS) [4] and performed two engineering tests.

## 2. System Setup

The ShapeTape was integrated into the BARS hardware. As shown in Figure 1, the tape controller was mounted horizontally on a metal back pack frame (silver rectangle visible on the left hand side of the picture). The tape was laid along the top of the user's right arm and wrapped around the index
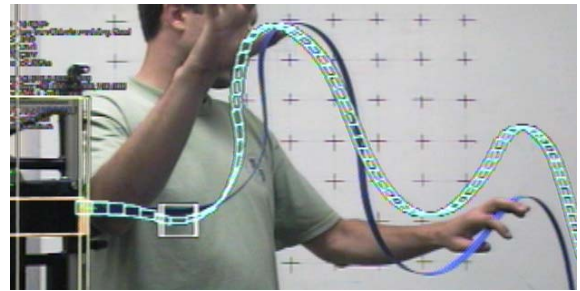


Figure 1: Virtual Tape (Light) Overlaid on Top of the Real Tape (Dark)

finger of the user's right hand. The excess tape was looped in the user's palm.

The ShapeTape API divides the tape into a set of segments. The attitude of each segment is calculated directly. The calibration process consisted of calculating fixed offsets for each of these measurements. The tape was held horizontally and the offsets were calculated directly. To assess the accuracy of the calibration, we used the BARS system to synthesise a virtual tape and overlaid it on a video of the real world which was captured by a calibrated video camera. Figure 1 shows the typical results of the calibration exercise and reveals several issues with the ShapeTape. First, because the position of a segment $s$ is found by integrating all previous measurements, errors accumulate. In particular, errors near the base of the tape lead to very large errors in its end. Second, the calibration tends to drift over time. Therefore, it was necessary to perform the calibration procedure multiple times within any experimental run. Third, despite careful calibration, we were not able to achieve very accurate tracking results. Figure 1 shows the accuracies still present even after the calibration process.

## 3. Experiments

### 3.1. Angular Pointing

We first tested the performance of ShapeTape as a pointing device. A two–dimensional grid of $9 \times 9$ points was precisely drawn on a white board. The grid was positioned and centered to create a field of view of 45 degrees horizontally and vertically for the user. The ShapeTape controller was
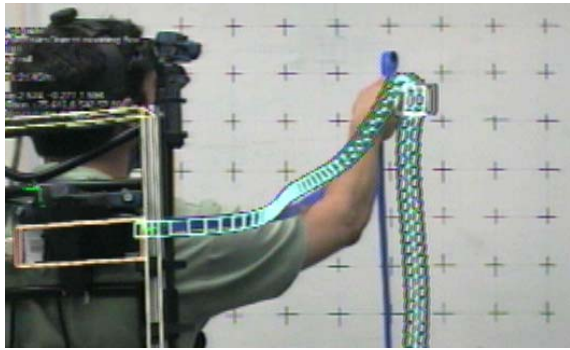
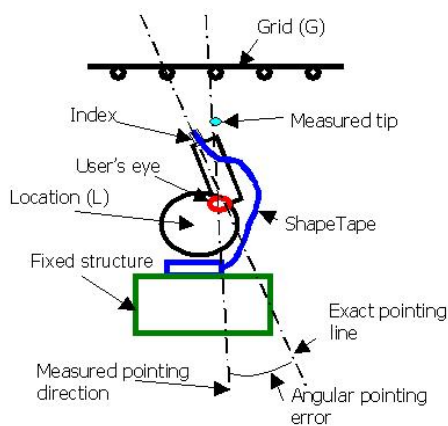Figure 2: User Performing Pointing Operations in Pointing Experiment



Figure 3: Overhead View of the Pointing Experiment

placed at a known fixed position corresponding to the location on the user's back. This eliminated errors from the body tracker. As shown in Figure 2, the experiment required the user to point at each grid sample using their tracked finger. An overhead view of the user pointing at the grid points is shown in Figure 3.

The position of the pointer for each point of the grid was recorded as well as the position of the user's eye during the pointing. The position of the user's eye was determined from a head-tracked helmet. Azimuth and elevation pointing errors were calculated from the angular difference between the line going through the user's eye and the position of the point on the grid and the line going through the user's eye and the measured position of the tip of the ShapeTape. We found that angular pointing errors increased as the user deviated from the calibrated position and could be as high as $10°$. This suggests that the angular resolution of object placement for a given environment should not be smaller than $10°$ if one wants to select objects without errors. This granularity is too high for our application.

### 3.2. Gesture Recognition

Although it is not accurate enough for unstructured pointing gestures, ShapeTape might be sufficiently accurate for gesture-based interaction where absolute accuracy is of limited importance. Therefore, we investigated the use of ShapeTape as a method for entering text. The position of the tape's end segment was recorded and, after projecting the points onto a two-dimensional plane, the results were sent to a Graffiti gesture recognizer [5]. The user interface toolkit SATIN [6] was used to perform this task.

Several users were able to successfully enter text into BARS. However, users indicated that keeping their arm high up in order to draw the string was not comfortable, and as a consequence their gestures were inexact with respect to what they wanted to draw.

## 4. Summary and Conclusions

We investigated the appropriateness of Measurand's ShapeTape device for wearable mobile interaction. We performed two experiments: one to assess the absolute pointing accuracy of the tape, the other to assess whether it can be used in a gesture-based recognition system. Pointing errors were found to be unacceptably large, and could be as high as $10°$. However, it was accurate enough for users to enter text using a Graffiti-based gesture recognizer. Therefore, we conclude that ShapeTape is not appropriate for interactions which require a high degree of accuracy. However, ShapeTape is capable of reproducing the qualitative motion the user is performing and thus could be used to support 3D interaction.

## References

[1] B. Thomas, V. Demczuk, W. Piekarski, D. Hepworth, and B. Gunther, "A Wearable Computer System with Augmented Reality to Support Terrestrial Navigation", in *IEEE International Symposium on Wearable Computers*, Pittsburgh, PA, Oct. 1998, pp. 168–171.

[2] Eric Foxlin and Michael Harrington, "WearTrack: A Self-Referenced Head and Hand Tracker for Wearable Computers and Portable VR", in *IEEE Symposium on Wearable Computers*, 2000.

[3] "ShapeTape – ShapeTape Captures 3D Data Using a Thin Sensorized Ribbon", www.measurand.com, Sept. 2002, accessed September 2002.

[4] S. Julier, Y. Baillot, M. Lanzagorta, D. Brown, and L. Rosenblum, "BARS–Battlefield Augmented Reality System", in *NATO Symposium on Information Processing Techniques for Military Systems*, Istanbul, Turkey, Oct. 2000.

[5] D. Rubine, *The Automatic Recognition of Gestures*, PhD thesis, Carnegie-Mellon University, Pittsburgh, PA, 1991.

[6] J. I. Hong and J. A. Landay, "SATIN: A Toolkit for Informal Ink-based Applications", in *ACM User Interfaces and Software Technology*, San Diego, CA, 2000, pp. 63–72.