UNCERTAINTY OF MEASUREMENTS USING MULTISENSOR CMMs

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INTRODUCTION

Hybrid, or multisensor, CMMs are growing in popularity due to the flexibility of changing the sensing device without having to re-establish the part's coordinate system. This allows us to determine a datum reference frame from physical features that may be measured (for example) with a touch trigger probe, and then inspect small or fragile features with a non-contacting system, while maintaining the datum reference frame already determined. While the assessment of the errors or uncertainty present in the use of each probing system is much like that described in the existing B89.4.1 standard, the quality of measurements relying on points taken with different sensors is more complex.

In this paper we report our implementation of proposed changes to the B89.4.1 standard as an initial assessment of the Hybrid CMM performance. In addition, we discuss testing methods that will expose errors or changes in the relative offsets of the different sensors. The primary focus of our work is a better understanding of the uncertainty introduced when measuring the same work piece with different sensors (dubbed "sensor fusion errors" by Tom Charlton [1]), and the development of artifacts and procedures to document this uncertainty. This paper will present the initial results of our experiments, and introduce methods to evaluate these data for both performance and diagnostic information.

Key Words: *Multi Sensor CMMs, Opto-mechanical hole plate*.

PRESENT WORK

We have performed two types of measurements on the multisensor CMM at UNC Charlotte. The first measurements involve the comparison of individual features using different sensors; these are meant to expose errors in a similar manner to the B89 multi-tip tests. The second measurements utilize an artifact called an "opto-mechanical hole plate" shown in Figure 3, and are intended to reveal errors in the machine volume that may be different for the different sensors. This work builds on earlier work with our multi-sensor CMM [2] and on characterization of video sensing CMMs [3] conducted at UNC Charlotte.

Sensor offsets

In the first measurement setup, we calibrated the touch probe and vision sensor on a common setting ring, and then measured a different ring and a gage block at the other end of the measuring volume of the machine. The setting ring was in the lower left edge (0, ½, 0) of the CMM volume, and the other artifacts were in the upper right edge (1, ½, 1) of the measuring volume. This arrangement is shown in Figure 1. A common origin was set at the center of the setting ring, and the larger ring (Ring 2) was measured 5 times with each sensor.

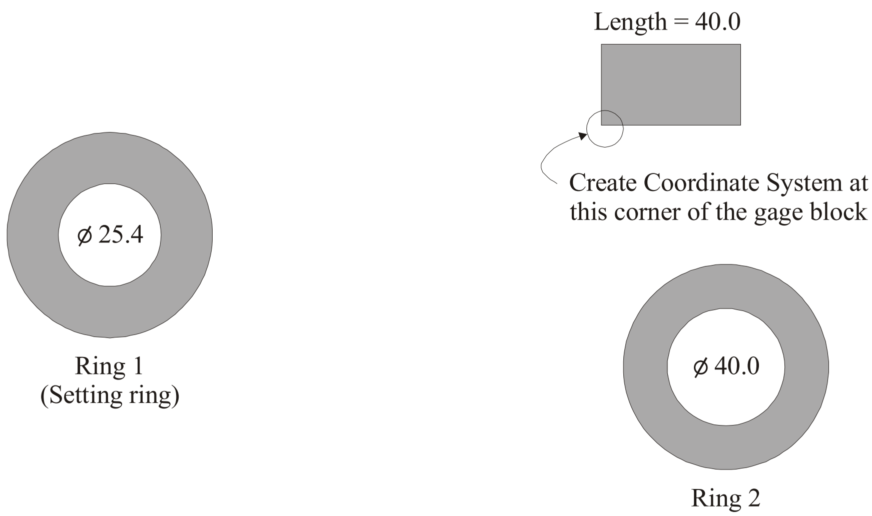

Figure 1: Artifact setup on multisensor CMM (gage block and Ring 2 are raised in Z)

The results of repeated measurements on the larger ring show some scatter in the center location of the ring for each of the two sensors, and systematic error between the sensors. To check that there was no excessive drift or hysteresis for either sensor, we returned to the setting ring after each measurement and reverified its location. The total scatter for both sensors was less than 3 micrometers in x and y, which leads us to conclude that there is some difference in the machine errors and compensation as we traverse the machine volume.

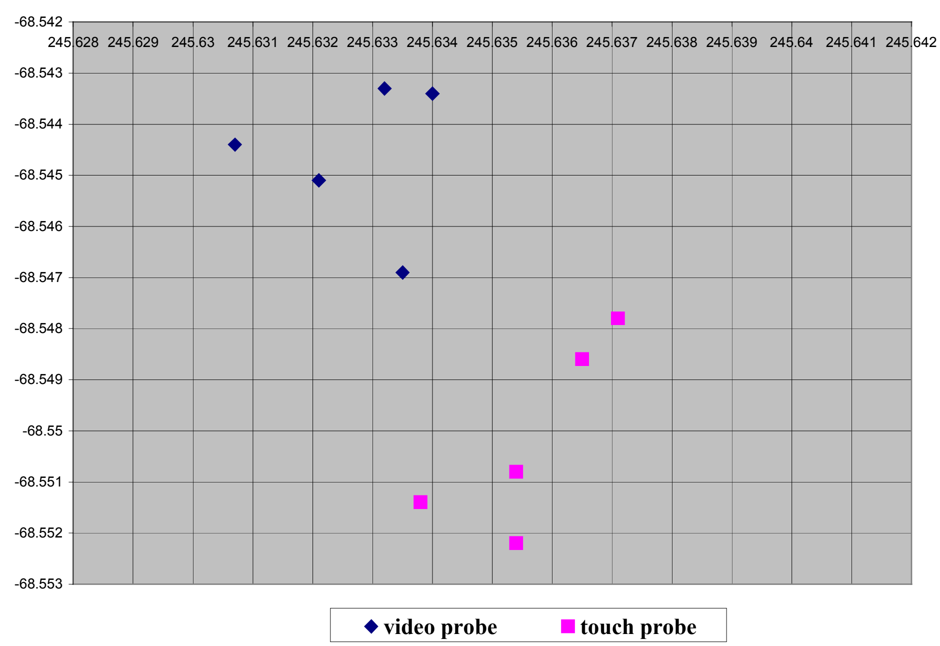

Figure 2: Comparison of Ring 2 center location measurements (1 micrometer grid).

Although not shown in this short abstract, we also found significant offset (over 20 μm) between measurements taken with the touch and video probes on the smooth gaging surface of the gage block. This is due to the highly reflective surface being measured in conjunction with a lack of experience with various illumination techniques. While there may be better ways to measure this surface than we used, illumination remains a bit of a "black art" in video-sensing measurements.

Hole plate measurements

The next set of experiments used an opto-mechanical hole plate, provided by our colleagues at the Technical University of Denmark. This plate, shown in Figure 3, has a 100 μm thick stainless steel sheet captured between two heavier plates. The features measured in our experiments are the smaller through-holes which are spaced at a nominal dimension of 20 mm. Two features of this artifact that make it particularly useful for our project. The first is that the center sheet is both thin enough that the circular features are essentially two dimensional (facilitating video measurements) and thick enough that a touch probe can perform adequate contact measurements. The second nice feature is that the artifact can be "flipped" in the x- or y-direction, yielding simpler reversal mathematics than when repeatedly rotating the artifact.

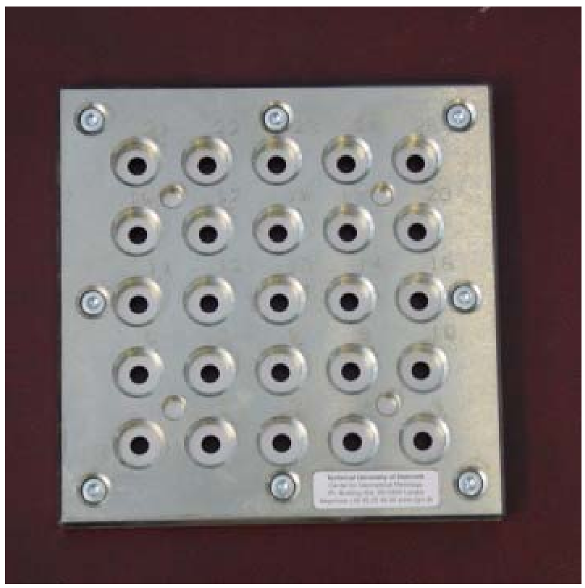

Figure 3: Opto-mechanical hole plate.

We have measured the hole plate in four orientations – listed in Table 1 – to permit the extraction of both CMM and artifact errors. The plate is positioned nominally in the center of the CMM volume, and to date we have measured it with a contact probe on our Leitz PMM to establish reference values for the hole locations, and with the video probe on our multisensor CMM.

Table 1. Positions of the Hole Plate

No.	***Description***
I	Start position
II	Plate flipped about the X-axis, reversing the y-coordinates relative to the start position.
III	Plate flipped about the Y-axis, reversing the x-coordinates relative to the start position.
IV	Plate rotated 180 degrees about its center, reversing both x- and y-coordinates.

The plot shown in Figure 4 is typical of the results we obtain. This plot compares the measurements taken in position I and position II. In every case, the origin and coordinate system of the plate is constructed using the same physical features, so the extraction and separation of errors is slightly different than in the conventional reversals. In Figure 4, the deviations are shown magnified by 2000 times. This means that the 20 mm squares corresponding to the hole locations represent 10 μm when looking at the deviations between two measurements.

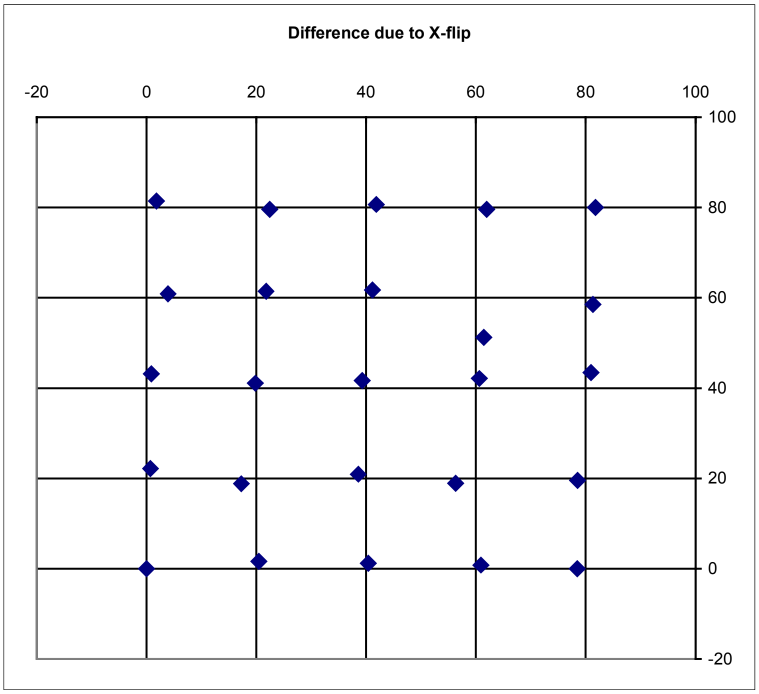

Figure 4. Comparison of measurements after reversal (see text for notes on scale).

Future Work

This work will soon include measurements on the multisensor CMM using *both* the video and touch probe, which will help us separate errors in the CMM due to sensor changes from uncorrected errors in the machine structure. In addition, comparison to other measuring machines will allow us to assess the range of errors that can be revealed with an artifact of this type.

Acknowledgements

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References

[1] Charlton, T., "Sensor Fusion Errors in Multi-Dimensional Coordinate Measurement", *Proc. International Dimensional Workshop*, Nashville, TN, May 2003.

[2] Thakkar H H., *Characterization of Hybrid Coordinate Measuring Machines*, M.S. Thesis, University Of North Carolina at Charlotte; 1998.

[3] Salsbury J G., *Three Dimensional Metrology of Video Coordinate Measuring Machines*, Ph.D. Thesis, University Of North Carolina at Charlotte; 2000.