Parameter Calibration of Articulated CMM

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Abstract:

Articulated CMMs are widely used to measure a large scale work and/or a complicated work, as it is very flexible. On the other hand, to measure the works, the kinematical parameters should be calibrated in advance of measurement. We planed and tested an artifact. The artifact has nine spheres with different heights on the flat plate. The kinematical parameters are calibrated based on the measurement result of all spheres on the artifact. In this paper, we will describe the model of the articulated CMM, the structure of the artifacts and the result of parameter calibration. We will compare the kinematical parameters calibrated by the artifact in different locations and orientations. After parameter calibration, we show that the calibration to use the artifact is useful for wider area and the measurement result by CMM is correct.

Introduction

Articulated CMMs are widely used to measure a large scale work and/or a complicated work, as it is very flexible. On the other hand, to measure the works, the kinematical parameters should be calibrated in advance of measurement. We calibrated an articulated CMM which has six rotational joints. We used nine spheres fixed on the flat plate as the artifact and used the concave conical shape as a stylus. When this stylus contacts with these spheres, the distance between the center of sphere and the top of the stylus is always same length. Therefore this articulated CMM can directly measure the center of sphere. The kinematical parameters are described in DH notation. These parameters are calibrated by comparing the result of measurement of 3DBP and the calibrated coordinates of center of spheres.

After calibration, we estimated the effectiveness of the calibration and the correctness of the calibration by 3DBP in different locations and orientations.

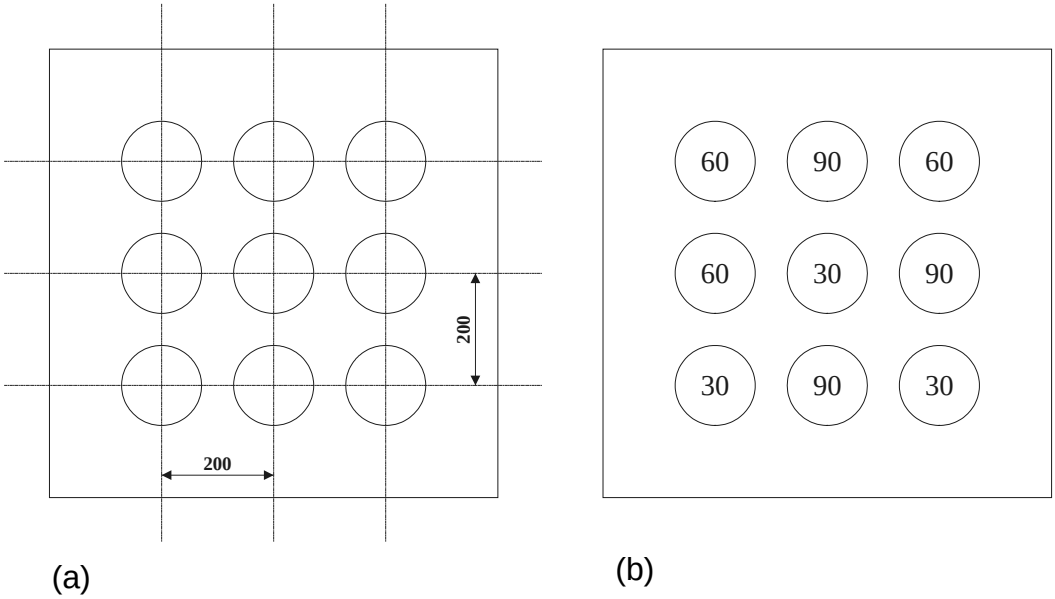
Model of articulated CMM

The articulated CMM in our project has six rotational joints. In the DH notation, four kinematical parameters are necessary for each joint. As the base arm could be fixed in any locations and orientations in world coordinate system, three parameters could be reduced. The artifact should be calibrated in advance by any methods and described in the workpiece coordinate system on the artifact itself. The center of spheres are measured by the articulated CMM in world coordinate system and the calibrated coordinates of the center of spheres are described in the workpiece coordinate system. Therefore, six parameters are necessary to convert from the world coordinate system to workpiece coordinate system. Totally, the number of kinematical parameters is 27(=4*6-3+6). However, six additional parameters are necessary to calibrate the kinematical parameters based on the artifact, but they are not necessary in measurement.

Artifact with nine spheres

The artifact is shown in figure 1. The artifact has nine spheres on the flat plane and is called 3DBP. These spheres are measured by the ordinary CMM and the center of spheres are calibrated. As the accuracy of the ordinary CMM is higher than that of the articulated CMM, the measured centers by the ordinary CMM are enough

accurate to be used as the calibrated coordinates of center of spheres.



(a) (b)

figure 1: Configuration of artifact: (a) shows the location of spheres in horizontal plane. (b) shows the height of spheres from the flat plane.

Procedure of calibration

As the number of kinematical parameters are 27, 27 equations are necessary to determine the parameters. When nine spheres are measured , 27 equations are just derived. In this paper, to get more precise kinematical parameters, nine spheres are measured five times. Finally 27 kinematical parameters are solved by non-linear least square method.

The kinematical parameters have the uncertainty, the amount of the uncertainty is depend on the location and the orientation of the artifact. So, we put the artifact in seven different locations and orientations. Figure 2 shows the examples of different locations and orientations. Totally seven groups of kinematical parameters are solved by non-linear least square method. The kinematical parameters are a little bit different from other groups.

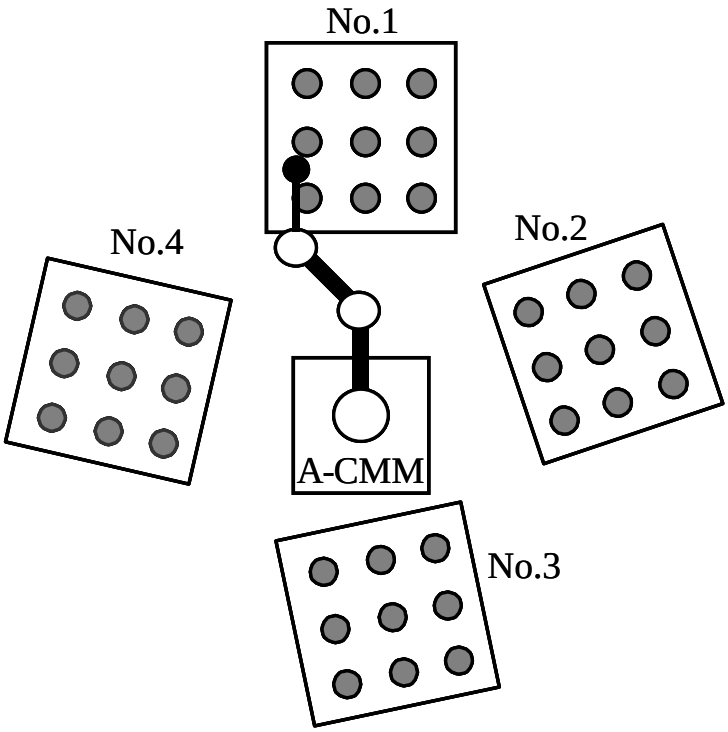


figure 2: The artifact is put in some different locations and orientations.

Result of Calibration

So, the combination of column n and row n means the data in the artifact are used for calibration of kinematical parameters and estimation of kinematical parameters. Therefore the value in column n and row n is smaller than others.

Location 6 and 7 are worse than others in both kinematical parameters and measured values. As the artifact in location 6 and 7 are put in tilted orientation and it is difficult for the articulated CMM to accurately contact with the spheres, these results could be affected by the mis-contact and the bending of the arm of CMM.

It is proved that the kinematical parameters are useful to measure wider area from location 1-5.

Estimation of Kinematical Parameters

The Ball-Bar(KOBA) is measured to show that the kinematical parameters are absolutely calibrated. This Ball-Bar has five balls. The distance between two balls is 250mm. The Ball-Bar is put in four different locations and orientations and five balls are measured 5 times. After that, the measured values are converted to the coordinate system of the articulated CMM and the distances between two balls are calculated. The results in location 1 to location 5 fit about 250mm.

Therefore it is proved that the kinematical parameters are calculated well and the articulated CMM is absolutely calibrated.

At this moment, the diameter of sphere of 3DBP is 20mm and that of Ball-Bar is 30mm. The contact point between the conical stylus and Ball-Bar is different from 3DBP. This compensation is necessary to measure the distance between two balls. This result shows that the stylus could be changed after calibration process.

Summary

1. The articulated CMM with six rotational joints are modeled in DH notation.
2. Nine spheres, which are located in three dimensional space, is used as the artifact.
3. It is shown that the location and orientation of the artifact affects the calibration of kinematical parameters.
4. The calibration of kinematical parameters is confirmed by measuring the reference length(Ball-Bar).