EVALUATION OF TASK SPECIFIC UNCERTAINTY FOR CMM MEASUREMENTS

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Introduction

The evaluation of measurement uncertainty is complex as there are a variety of sources of errors and variation. The task of combining all the sources of errors, according to the guidelines in GUM [1], to come up with an uncertainty budget is not an easy one. There is no single uncertainty statement that can be generally applied to all CMMs. The uncertainty for every individual CMM is specific to a particular task and depends on various issues like sampling strategies, probe errors, residual systematic errors, fitting algorithms used and the ambient conditions.

There are a couple of approaches to evaluate measurement uncertainty for a CMM that are currently in use. The first method involves extracting all possible information from the performance evaluation of a CMM to estimate the measurement uncertainty. This method is however not always feasible for the reason that the performance evaluation is done for the total working volume of the machine. The measurement, however, is done at a certain location within the working volume, which is why the evaluation results cannot be translated into uncertainty estimates. The second method involves the comparison of the part under study to a well-calibrated artifact. The selected artifact must be, in reasonable measures, identical to the part under study. The ambient conditions for measurement of the artifact and the part under study must be identical to the extent possible. This method can give good estimates of measurement uncertainty if the artifact corresponding to the part is available. The obvious drawback to this method is the non-availability of well-calibrated artifacts for every part manufactured.

Virtual CMM and Computer Simulation

The work presented in this paper demonstrates the use of computer simulation to determine the measurement uncertainty for CMM measurements. The idea behind this approach is to simulate the conditions of measurement identical to the actual measurement conditions to a reasonable degree. Fig. 1 shows the schematic of the approach adopted.

Initial set-up

The implementation of the virtual simulation has been done with the aid of Matlab®. The initial task is to set-up the working volume of the measuring machine. The maximum possible travel by the X, Y and the Z axis make up the working volume of the coordinate measuring machine. All the measurements are made within the working volume of the CMM. The machine zero is fixed and this will constitute the machine coordinate system for the measurements. The virtual part is simulated based on the part drawing and placed on the virtual CMM. This is done by first setting up the part zero with reference to the machine origin. The bounding values of the various elements constituting the part are established and so are the datum planes. The part, in general, is constituted of elements like lines, planes circles, cylinders, cones and spheres.

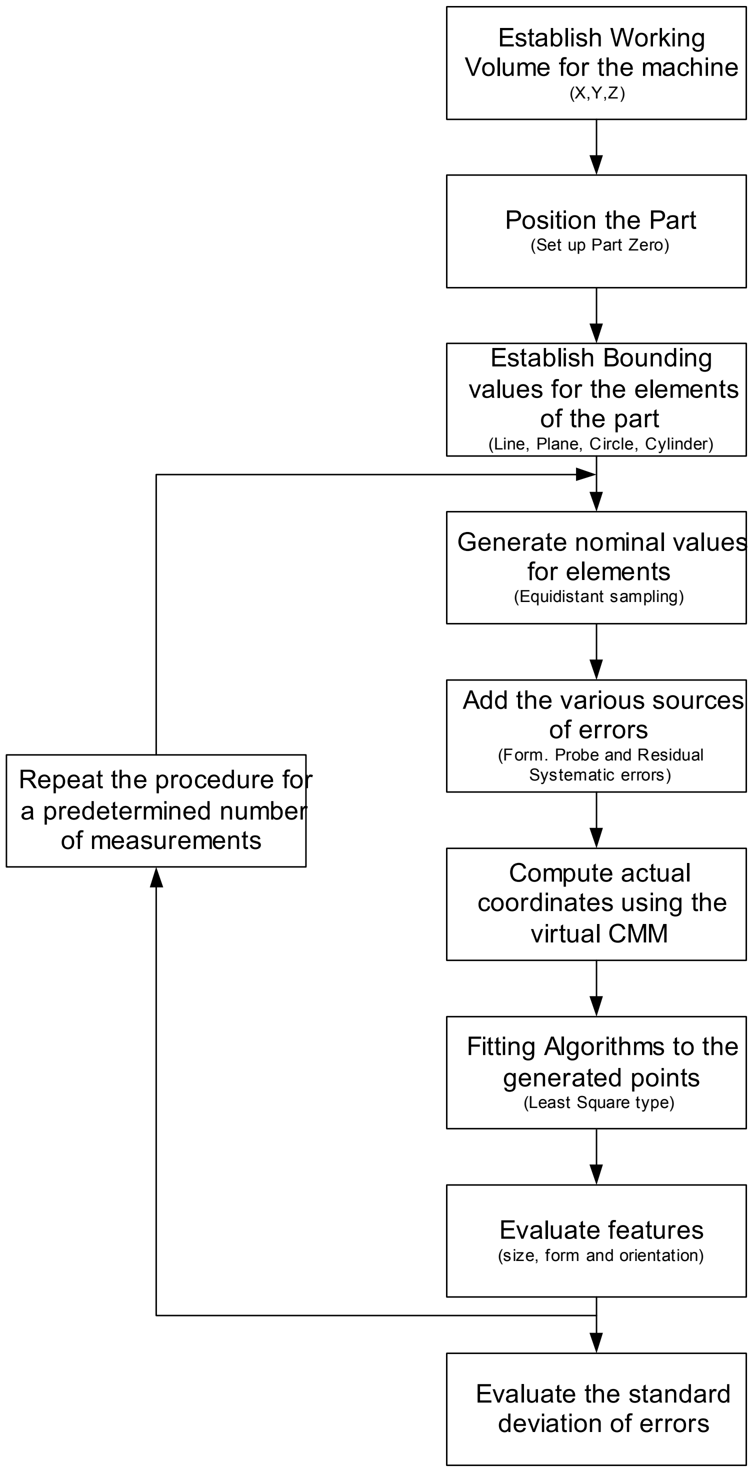

Fig. 1 The Virtual CMM approach

Virtual measurement

The measurement process starts by generating the nominal values using equidistant sampling. There are other techniques of sampling like the random sampling, stratified sampling etc. that could be used. The various errors are then modeled based on the nature of errors. The form error on the part is modeled as a sine wave with the required amplitude and the no. of cycles. The probe error is modeled as a uniform distribution with the required amplitude of the density function. Noise is added according to a Gaussian distribution with the required confidence level and the amplitude of the density function.

The virtual CMM developed by Babu [2] was used for the determination of measurement uncertainty in measuring features on the virtual part. The parametric errors were determined by using a calibrated ball step gage which is a 1-D array of precision spheres. The function of the virtual CMM is to determine the coordinates of a point as if it were measured on an actual CMM.

The nominal values of the measurements with the form, probe, systematic and random errors are fed into the virtual CMM. The resulting values are the actual values of the measurement. The substitute geometry for each of the elements is then determined by appropriate fitting algorithms. Least square fitting algorithms [3] were used for the purpose of this research since these algorithms are very well established and also easy for implementation. Once the elements are established, various features can be measured either in a single element or a combination of elements. Various features like perpendicularity, parallelism and angularity (orientation), circularity, flatness, straightness and cylindricity (form) could be determined. The diameter of a circle (size) or the distance between two points (length) could also be evaluated.

The procedure described above is repeated for a predetermined number of measurements and the resulting errors are analyzed by statistical tools to get an estimate of the standard deviation. The results are plotted and the measurement uncertainty is reported with a coverage factor.

Results and Conclusion

The above procedure to estimate the measurement uncertainty is used to evaluate the diameter and form measurement of a circular feature measured on the CMM.

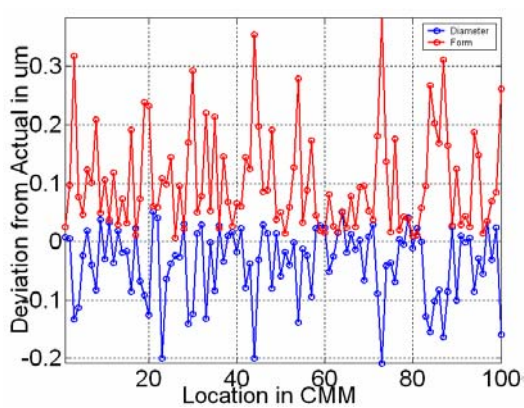

Fig. 2 Measurement Uncertainty for a circle measured at 100 locations in the XY plane
Uncertainty in Diameter: 50mm (nom) – 0.379 μm (2σ) Form – 1.002 μm (2σ)

First the nominal circle is generated with inputs being the specified diameter, measurement plane and the center point (x_0, y_0, z_0). The actual coordinates are then obtained by feeding the nominal values to the Virtual CMM. A least squares circle is fitted to the actual coordinates obtained and the diameter and form error are computed. The errors indicate the deviation from the nominal values of measurement. This procedure is repeated for a specified number of measurements (in this case, 100) and the values are plotted as shown in Fig. 2. The measurement uncertainty is reported as a standard deviation of the parameters measured namely, diameter and form errors. There is also an ongoing effort to include characteristics like size and orientation (perpendicularity, parallelism and angularity) for planar features.

The procedure for evaluating the measurement uncertainty using a Virtual CMM and computer simulation is a practical approach. However the various errors modeled here are simple and a more detailed error analysis should give better estimations. The errors can be modeled and plugged in to this routine by writing more detailed M-files to give the expected results.

References

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