Form error estimation in the assessment of product geometry via Kriging prediction

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Abstract

We focus on the inference on the errors present on different planar surfaces controlled by using a Coordinate Measuring Machines (CMM). These errors, that usually have a typical pattern related to the employed manufacturing process, are limited by means of dimensional and geometrical tolerances (such as straightness, roundness, flatness, profile) that have to be assessed on the manufactured parts. Industrial parts usually show typical geometric deviation pattern due to the manufacturing processes used for their production under the same condition. These patterns are referred as manufacturing signatures. In a number of situation, the measurements may be also affected by systematic errors of the CMM measurement process, e.g. caused by a bad part alignment during the measurement process.

In the present paper we consider a spatial dependence between the measured points; for this purpose we suggest the use of a Kriging model in the prediction of the not measured points of the surface of the part. Kriging is a stochastic linear interpolation technique that predicts the response values at untried locations with weights assigned to the tried locations. The weights are selected so that the estimates are unbiased (repeatedly Kriging we expect the correct result on average) and they have minimum variance. The key modelling feature is the rate at which the variance between points changes over space. The spatial dependence may be expressed as a variogram which shows how the average difference between values at points changes; it is a function of the distance and of the corresponding direction of any pair of points depicting their correlation extent. Theoretically, it is defined as the variance of the difference between the response values at two locations and it is equivalent to the correlation function for stationary processes. The use of the variogram instead of the correlation function is recommended by the geostatisticians even if the process is not stationary.

We simulate different, and most common, manufacturing signatures of a planar surface and possible errors of a measurement process with a CMM. The variograms relating to the simulated surfaces are estimated using the most robust empirical estimator in the case at hand and the likelihood (or restricted likelihood) estimator. The behavior of the omnidirectional variograms suggest an existing spatial correlations, giving evidence of possible non isotropy too. Given the detection of a model for the variogram trend, this is removed from the data with a suitable model fitting the data. A new variogram is then estimated from the residuals, showing hopefully no correlation and possible the nugget effect. The aim is the improving of the Kriging model for providing more accurate predictions of the values in the untried points.

Keywords: Kriging Model, Spatial Correlation, Variogram, Anisotropy, Geometric Errors, Measurement Errors

References

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