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Inverse problems of measurement with application on specification of surface profile

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Introduction:
A contradiction of the specification of free-form surface is pointed out. The inverse problem of measurement (IPM) is defined based on the representational measurement theory. By using the concept of IPM, a desired property of specification limit is derived, and a correction for the contradictory situation is proposed.

Specification and measurement of surface profile

The upper and lower specification limits (LSL and LSL) of a free-form surface profile defined in ISO 1101 are two curves enclosing circles of certain diameter r, the centers of which are situated on the nominal surface profile (see figure 2a). For an actual surface profile l, if all the points lie within the tolerance zone, i.e., LSL < l < LSL, l is within the space.

The canonical method of measuring surface profile is contact measurement by moving a tactile stylus along the surface to be measured to obtain the locus of the central point of the stylus tip.

A contradiction of the specification of free-form surface

Due to the excessive property of closing filter, the estimated profile is always above the actual profile (see figure 1). Hence when an actual surface profile coincides with the LSL (lies within space), the measurement result (without errors) would, however, be out of space, which contradicts with the real situation.

A correction of the tolerance zone of surface profile

To estimate the surface profile according to the observed locus on an inverse problem, Ds is the forward mapping and its pseudo-inverse is Ed, in the sense that EdDs = Ds.

Essential reasons of the contradiction:
- The forward mapping Ds is not one-one;
- The inverse solution X is a maximal point of the possible input, i.e., l ≤ EdDs(l) ≤ X.

We expect that if the true value of a measured object is within space, its measured value is also within space. Hence the following desired property of space limits should be satisfied:
Let a be a limit, let X0 then γ ≤ X0 ≤ γ + a.

A proposed solution
- Correcting the curve of LSL from l0 to γ + C0(l0) (see figure 2b), where C0 is the closing filter with the structuring element $S$.
- The diameter of the stylus $S$ is assumed to be smaller than the dimension $e$. It can be proved with the important property of closing filter that the desired property is satisfied after the correction.

Acknowledgement: The authors gratefully acknowledge the UK’s Engineering and Physical Sciences Research Council (EPSRC) funding of the EPSRC centre for Innovative Manufacturing in Advanced Meturgy (Grant Ref. EP/E040342/1).

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