Data fusion of surface normals and point coordinates for deflectometric measurements

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Reflective surfaces can be measured by means of deflectometric measurement systems. If the measurement is done with at least two reference planes as proposed by Petz in 2004 [1], the measurement results are the point coordinates (through a triangulation process) and the normal direction (by calculating the bisector angle between incident and reflected light ray) for each valid measurement point. As the accuracy of the measured normals is up to three orders of magnitude higher compared to the accuracy of the point coordinates the typical evaluation strategy for continuous surfaces involves an integration of the measured normals. This method yields smooth results of the surface with deviations in the nanometer range but at the same time it is sensitive to systematic deviations, as the error is cumulated during the integration process. The measured point coordinates on the other hand do not suffer from this effect but the noise level is in the order of micrometer. This results in inconsistent data. As an alternative evaluation strategy a data-fusion process that combines both the normal direction and the point coordinates has been developed.

We propose to use a non-linear fitting technique to increase the accuracy of the point coordinate measurements. For every measurement of a point coordinate we define a calculated normal vector by the crossproduct with two neighboring point coordinates. We form an objective functional as the mean squared misfit of these calculated normals and the measured normals. Moreover, we use the estimated accuracy of the coordinate measurement to add a constraint on the maximal change of the coordinate measurements to the optimization problem. We use a projected gradient method to minimize to objective under the constraint. Our results show that the proposed method is able to perfectly adjust the point coordinate measurements to the measured normals and hence, leading to totally consistent data whereby increasing the accuracy of the point coordinates; Figure 1 shows an example of a measurement of a plane surface. Before data fusion the error between the normals on the surface defined by the point coordinates and the measures normals is up to 20°, after optimization the maximal error is below one degree.

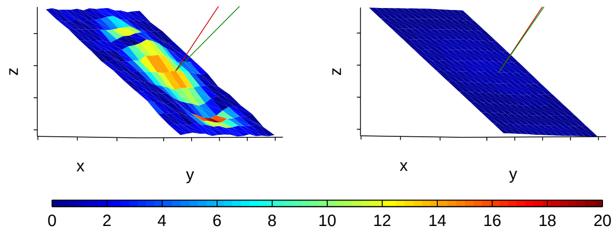

Figure 1: Left: Measured point coordinates. Right: Point coordinates after optimization. The red vector is a calculated normal, the green a measured normal. The color encodes the error between calculated normals and measured normals in degrees.

References

[1] Petz, M.; Tutsch, R.: Reflection grating photogrammetry. VDI-Berichte 1844, International Symposium on Photonics in Measurement, Frankfurt, 2004, pp. 327-338