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Publisher's version / Version de l'éditeur:

<https://doi.org/10.1117/2.1201102.003393>

SPIE Newsroom: Sensing & Measurement, 2011-03-09

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Assessing the Performance of 3D Imaging Systems

David MacKinnon, Jean-Angelo Beraldin, Luc Cournoyer, and Benjamin Carrier

Statistically-traceable procedures are presented to describe the performance of a 3D imaging system, using terminology selected to be familiar to those who regularly work with Geometrical Dimensioning and Tolerancing.

A variety of 3D imaging systems exist; however, there are few standards available to evaluate the performance of these systems. The National Research Council of Canada's Institute for Information Technology (NRCC-IIT) works with other research institutes in Canada and around the world to help define and refine emerging standards for 3D imaging systems. We have developed a series of statistically-traceable procedures for evaluating the geometrical performance of a system, as well as propose using terminology that should be familiar to technicians who regularly use Geometrical Dimensioning and Tolerancing (GD&T) procedures.

We begin with three classes of surface forms - plane, spheres, and freeform surfaces - and assess the precision, trueness, and surface response of a system. Precision is expressed as measurement uncertainty and trueness is expressed as measurement error^{1,2}. Surface response is a complex topic so will not be discussed here. Each surface form is provided as a certified reference surface (CRS) with associated certified reference values (CRV). Test procedures are used to generate values for flatness, roundness, angularity, diameter error, angle error, sphere-spacing error, and unidirectional and bidirectional plane-spacing error that are statistically linked to a CRS through its CRV.

1 Geometrical performance

Measurement precision represents the spread of measurements about a model of the CRS. A best-fit procedure is used to minimize the uncertainty and a precision characteristic value is generated to indicate the size of the spread. If the CRS is a plane then the associated GD&T term is Flatness (F)³. We define

F to represent the size of the region within which is found at least 99.7% of measurements generated by the system, similar to a method described in the VDI 2634 Part 2⁴. If the CRS is a sphere then the associated GD&T term is Roundness (R)³, which we define in a similar manner.

The maximum F and R values generated in the working volume are associated with the system. Of particular interest to GD&T technicians is the effect of plane orientation on F so we adapt the GD&T term Angularity A to represent the largest F value generated when the CRS is angled with respect to the depth axis. The repeatability (uncertainty) of F and R are obtained using repeated measurements, then tested to ensure that they are significantly larger than the corresponding CRV.

Measurement trueness represents the difference between a CRV and a measured value. If the CRS is a sphere then the diameter error (E_D) compared to the CRV for sphere. The sphere-to-sphere distance is described in the VDI 2634 Part 2⁴ so we define a similar term, sphere-spacing error (E_{SS}). Plane separation is also an important component so we define the unidirectional (E_{UPS}) and bidirectional (E_{BPS}) plane-spacing errors. Finally, we define the angle error (E_a) between planes. In all cases the repeatability of the error values are generated so that they can be compared to the appropriate CRV to verify that no error value is significantly different than the reference value.

2 Conclusion

We have briefly described a series of statistically-traceable procedures designed to evaluate the flatness, angularity, roundness, diameter error, sphere-spacing error, unidirectional and bidirectional plane-spacing error, and angle error of a 3D imaging system, but these procedures describe only the geometrical performance of a system. The test suite being developed by the NRCC-IIT includes measures of model fidelity, resolution, and optical properties, associated reference surfaces, and procedures to measure system repeatability, intermediate precision, and re-

Continued on next page

producibility. These procedures can be tailored for application-specific analysis, and the terminology has been adopted to be familiar to the typical end-user in an industrial environment.

Author Information

**David MacKinnon, Jean-Angelo Beraldin, Luc Cournoyer,
and Benjamin Carrier**

National Research Council of Canada
Ottawa, Ontario, Canada

David MacKinnon is a Research Associate at the National Research Council of Canada's Institute for Information Technology (NRCC-IIT). A former statistician with a doctorate in Systems Engineering, he now develops statistically-based methods for assessing the performance of 3D imaging systems.

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