Int J Comput Vis (2013) 102:56–72
DOI 10.1007/s11263-012-0570-3

GD&T-Based Characterization of Short-Range Non-contact 3D Imaging Systems

David MacKinnon · Benjamin Carrier · Jean-Angelo Beraldin · Luc Cournoyer

Received: 31 October 2011 / Accepted: 4 September 2012 / Published online: 13 October 2012

Abstract We present a series of test metrics, artifacts, and procedures for characterizing and verifying the operating limits of a short-range non-contact three-dimensional imaging system. These metrics have been designed to correspond to dimensioning and tolerancing metrics that are widely used in industry (e.g. automotive, aerospace, etc.). We introduce operating limit metrics that correspond with the geometric dimensioning and tolerancing (GD&T) metrics of Form (Flatness and Circularity), Orientation (Angularity), Location (Sphere, Corner, and Hole Position Errors), and Size (Diameter, Sphere-spacing, Plane-spacing and Angle Errors). An example is presented to illustrate how these metrics, artifacts, and associated test procedures can be used in practice.

Keywords Characterization · GD&T · 3D imaging systems · Quality analysis · Spatial metrology · 3D metrology

1 Introduction

A significant issue for companies implementing short-range (1 cm to 3 m depth-of-field) non-contact three-dimensional (3D) imaging systems into their production process is how to decide in which technology to invest. Short-range non-contact 3D imaging systems of sufficient quality for use in an industrial setting typically involve a significant investment when considering the cost of equipment, training, software, and maintenance contracts over the functional lifetime of the system. Few methods are available to help companies navigate the myriad of products and associated quality claims. Moreover, the "best" system for one application may not be as ideally suited for another. The lack of characterization standards makes it difficult to select a system based on information provided by the manufacturer because the published characteristic values, and the methods used to compute them, can vary among different systems.

From the perspective of the 3D imaging system's manufacturer, the measuring limits of a system should be obtained using standardized methods so that the manufacturer can provide specifications that mean something to the customer. Standardized methods for performing characterization of short-range non-contact 3D imaging systems, referred to here simply as 3D imaging systems, would also make it possible for the manufacturer to identify the strengths and weaknesses of their system, allowing them to better focus their efforts on product improvement.

The few guidelines and standards available for 3D imaging systems have emerged from the world of Coordinate Measuring Machines (CMMs). ISO 10360 is an international standard that describes methods for the acceptance and re-verification of CMMs. Parts 1 through 6 deal specifically with contact-probe CMMs, but a part 7 was added to include imaging-probe CMMs (ISO 10360-7: 2011). ISO 10360-7 intentionally parallels ISO 10360-2 so is also based on methods and terminology that were primarily designed for CMMs. The VDI 2634, a set of German guidelines, was then introduced and included a part devoted to acceptance and re-verification testing of optical non-contact 3D imaging systems. Part 2 was limited to optical non-contact 3D imaging systems that perform area scanning from a single viewpoint (VDI 2634 Part 2 2002) and Part 3 extended the test procedures to multi-view non-contact 3D imaging systems (VDI 2634 Part 3 2008). Like the ISO 10360-7, the

D. MacKinnon (✉) · B. Carrier · J.-A. Beraldin · L. Cournoyer
National Research Council of Canada, Ottawa, ON, Canada
e-mail: david.mackinnon@nrc-cnrc.gc.ca