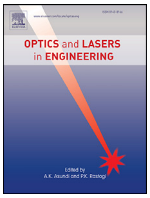
Optics and Lasers in Engineering 110 (2018) 193–206

Contents lists available at ScienceDirect

Optics and Lasers in Engineering

journal homepage: www.elsevier.com/locate/optlaseng



New procedure for qualification of structured light 3D scanners using an optical feature-based gauge

Susana Martínez-Pellitero[a,*], Eduardo Cuesta[b], Sara Giganto[a], Joaquín Barreiro[a]

[a] *Department of Manufacturing Engineering, Universidad de León, Escuela de Ingenierías, Industrial, Informática y Aeroespacial, 24071 León, Spain*
[b] *Department of Construction and Manufacturing Engineering, University of Oviedo, Campus de Gijón, Edificio 5, 33204 Gijón, Spain*

ARTICLE INFO

Keywords:
3D optical scanner
Structured blue-light scanning
Metrological evaluation
Feature-based gauge
Fringe projection sensor

ABSTRACT

This work evaluates the performance and operative limits to the dimensional accuracy of 3D optical scanning based on blue-light fringe projection technology. This technology, also known as structured light 3D scanning, is widely used in many reverse engineering applications. It allows the user to quickly capture and create point-clouds, by using images taken at different orientations of white-or blue-light fringe projected patterns on the part. For the survey, a large and feature-based gauge has been used with specific optical properties. The gauge is endowed with canonical geometrical features made of matt white ceramic material. The gauge was calibrated using a coordinate measuring machine (CMM) by contact. Therefore, it is possible to compare the measurements obtained by the structured blue-light sensor with those obtained by the CMM, which are used as reference. In the experimentation, the influence of the scanner software in the measurement results was also analysed. Besides, different tests were carried out for the different fields of view (FOV) of the sensor. The survey offers some practical values and limits to the accuracy obtained in each configuration.

1. Introduction

This work presents a practical procedure for qualifying a scanner based on structured blue light for geometrical and dimensional tolerances (GD&T) verification. The idea of evaluating non-contact digitizing systems for metrological applications was addressed in past research [1,2]. The main research works use the methodology based on GD&T and CAD comparison, using prismatic parts composed of basic elements such as planes, cylinders, spheres and cones [3–5] or complex geometries like turbine blades [2]. The focus of the present paper is similar to this research, but with the focus on guaranteeing the traceability of the experiments using a calibrated feature-based gauge. This gauge materializes a set of GD&T specifications using several canonical features and it is made of a specific and very suitable material for optical measurement.

The scanner used in this paper is based on the fringe projection technique [6,7]. It uses a structured blue-light pattern projected onto the part to capture dense point- clouds over different surfaces in very short times. This feature makes this equipment suitable for a diversity of tasks in industry. Moreover, modern software tools for transforming point-clouds into surfaces have also aided in their industrial deployment. There are several devices based on different principles that employ different algorithms for point acquisition and later for surface reconstruction. However, even when referring to the same working principle (structured light with a fringe pattern or reference target image analysis), these systems can be equipped with one or two cameras, with different ranges and resolutions (from 2 Mpx to 12 Mpx), with or without turntables, with white or blue light, etc., which leads to a diverse range of 3D scanners.

For these reasons, among others, the attainable accuracy for non-contact 3D scanners still remains hard to quantify, due to several error sources and the number of factors involved [6,7]. In fact, there are “intrinsic” factors derived from the equipment itself, such as camera resolution, the mathematical model and the intrinsic calibration procedure [8–11], the angles between the part, camera and projector [12,13], etc. Another set of errors are those due to external sources, like the ambient light at the time of measurement [14,15] or the surface roughness and colours [14–16]. A good approximation to evaluate these errors is to establish certain types of reference artefacts (tetrahedra, freeform surfaces, etc.) to evaluate and quantify the global error [17,18].

Nevertheless, this methodology has not been followed by the development of universally accepted standards, nor by standard procedures and artefacts that permit the evaluation of conformity, or even the assignment of measurement error values to the reconstructed geometrical features, as is commonly done within any metrological instrument.

Therefore, and in spite of the dissemination of the VDI/VDE 2634 [19] German guideline (for optical 3D measuring systems), the accuracy of these measurement instruments is not clearly quantifiable and depends on many factors that need to be constrained. All these factors

---

[*] Corresponding author.

E-mail addresses: smarp@unileon.es (S. Martínez-Pellitero), ecuesta@uniovi.es (E. Cuesta), sgigaf00@estudiantes.unileon.es (S. Giganto), jbarg@unileon.es (J. Barreiro).

https://doi.org/10.1016/j.optlaseng.2018.06.002
Received 2 February 2018; Received in revised form 4 June 2018; Accepted 5 June 2018