Optics and Lasers in Engineering 47 (2009) 336–342

Contents lists available at ScienceDirect

Optics and Lasers in Engineering

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

A performance evaluation test for laser line scanners on CMMs

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ARTICLE INFO

Available online 10 July 2008

Keywords:
Laser line scanner
CMM
Performance testing
Dimensional measuring

ABSTRACT

This paper presents a performance evaluation test for laser line scanners on 3D coordinate measuring machines (CMMs). Laser line scanners are becoming more popular in recent years, mainly for free form inspection tasks and reverse engineering. Error specification of these scanners is difficult because of many influencing factors like surface quality, surface orientation and scan depth. Therefore, procedures for evaluation and verification of conventional contact probes (e.g. touch-trigger probes) are not appropriate for non-contact laser line scanners. A straightforward test method that uses a planar test artefact is proposed. It enables to identify the influence of in-plane and out-of-plane angle, as well as scan depth on systematic and random errors of the laser scanner. Experimental results show that the tested commercial laser scanner, after calibration, exhibits systematic errors of about 10 µm.

1. Introduction

Today laser line scanners are frequently used as an alternative for tactile probes on CMMs. Instead of touching the surface to determine coordinates, a plane of laser light is projected onto the surface (Fig. 1a). By capturing the shape of the projected intersection line with a digital camera, the coordinates of the points on the measuring surface are determined by triangulation.

Through calibration of the scanner, camera coordinates are linked with coordinates in the plane of laser light. Since the dimensions of the camera are limited, the scanner will also have a limited field of view (Fig. 1b).

The main advantages of laser line scanning probes, in comparison with conventional touch-trigger probes, are the possibility to measure contactless and to capture many points in a short period of time. This makes them especially useful for digitising free form surfaces. Fig. 2 shows a typical application of a laser line scanner: dimensional quality control of free form surfaces.

The most important disadvantages of laser line scanners, at this moment, are the limited accuracy and the strong influence of surface quality on this accuracy. It is very difficult to measure shiny surfaces, e.g. machined steel or aluminium, because diffuse reflection is needed in order to capture the projected laser line with the camera. The latest laser line scanners are better equipped to deal with this problem but the accuracy for shiny surfaces will always be lower than for diffuse reflecting surfaces. Therefore, metal parts are often sprayed with a diffuse reflecting coating before they are measured. This is of course a serious drawback for many applications. Apart from reflection problems, translucency of the surface also influences the results. Many plastic parts are slightly translucent, and so the laser light also slightly penetrates the surface. This problem can again be solved by applying a diffuse reflecting coating on the object. This of course also affects the measurement results.

Today laser line scanners are at least one order of magnitude less accurate than conventional touch-trigger probes. The accuracy of laser line scanners is difficult to define because standardised procedures to evaluate touch-trigger probes are not appropriate for laser line scanners due to important differences between the two. Firstly, laser line scanners are optical contactless probes while touch-trigger probes are mechanical contact probes. Secondly, a laser line scanner is a 2D measuring device while a touch-trigger probe is a contact sensor. The increasing use of laser line scanners on CMMs, but also on portable measuring arms, implies a growing need for reliable accuracy evaluation tests to analyse and improve the accuracy of the scanners.

The quality of pointclouds, obtained from laser line scanners, has been extensively investigated by Lartigue, Contri and Bourdet [1,2]. They introduced four parameters that describe the quality of a pointcloud: density, completeness, noise and accuracy. In this paper only noise and accuracy are considered, since these two are directly linked to the quality of the scanner. The other two depend strongly on the measurement strategy and object.

2. Artefacts for performance evaluation tests

Several authors proposed algorithms and artefacts for the calibration of laser line scanners [3–5]. Today, there are almost no

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doi:10.1016/j.optlaseng.2008.06.001

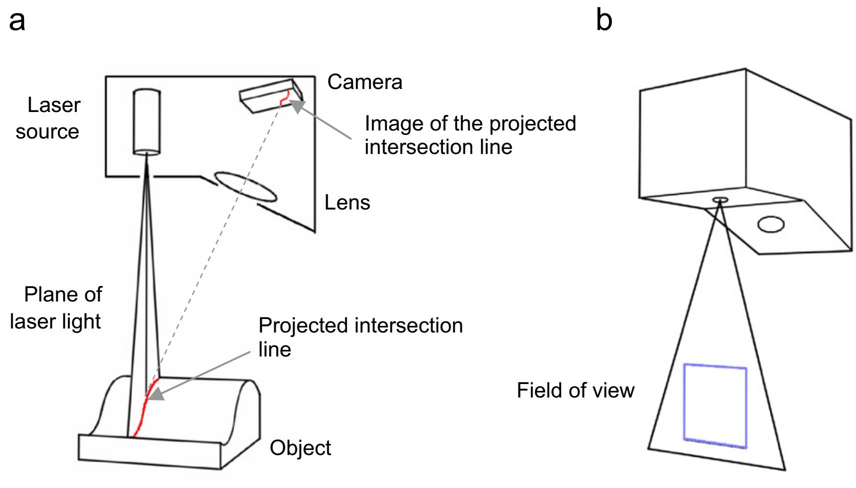

Fig. 1. Principle of laser line scanning (a) and resulting field of view of a laser scanner (b).

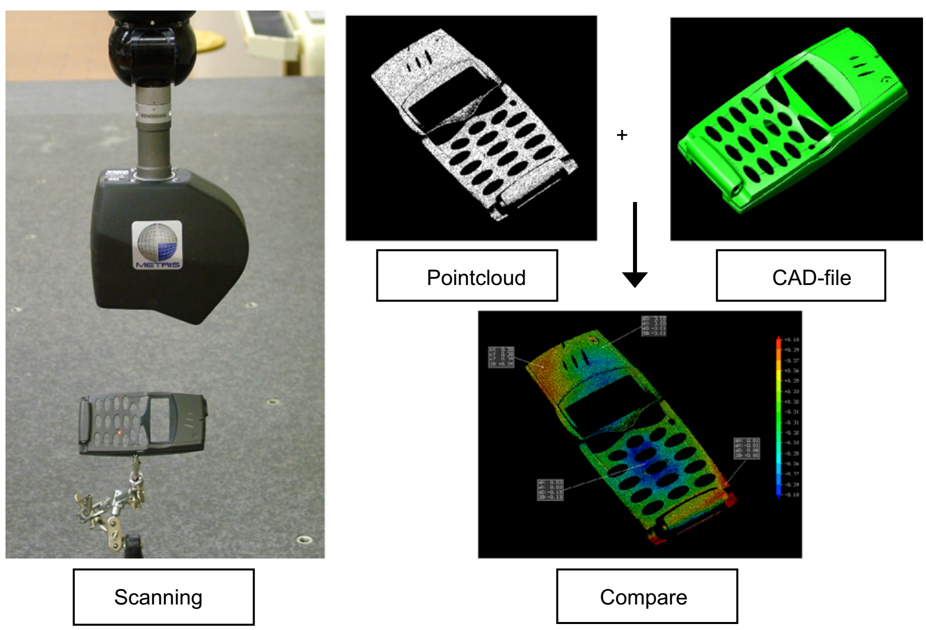

Fig. 2. Typical application of laser line scanners: dimensional quality control of free form surfaces.

publications about performance evaluation tests and artefacts for laser line scanners mounted on CMMs. Possible reference artefacts are illustrated in Fig. 3: single sphere, steps, single or multiple edges, sphere-plane combinations, faceted sphere and double-curved surfaces.

Often a reference sphere (Fig. 3a) is used as reference artefact. The advantage of using a reference sphere is the accordance to the approach standardised in ISO 10360 for verification of conventional touch-trigger probes and tactile scanning probes, where a sphere is also used. A common reference object is very important for the evaluation of multiple sensor CMMs. However, when the performance of a laser line scanner is evaluated using a reference sphere, results often do not correspond with errors noticed in practice.

Feng proposed a reference sphere mounted on a reference plane (Fig. 3d) to evaluate random and systematic errors of the laser scanner [6]. Others used complex artefacts like double-curved surfaces [7] or a facetted sphere [1]. Several artefacts were tested, but many are too complex and results are difficult to analyse.

When using a sphere, problems occur when only a segment of the sphere is scanned, which is always so when only one scanner orientation is used. Fitting a sphere through a small segment of data leads to unstable results (Fig. 4a). As a result, errors on sphere diameter and position are not an indication of the measurement errors of the scanner; they are rather an indication of an ill-conditioned fitting problem.

When using edge-like artefacts, the variance on tip position can be used as a performance indicator. However, to calculate the tip position, the intersection of 2 fitted lines needs to be calculated and the results are strongly influenced by the data length used to fit the lines. Even more important is the fact that the direction of variance of the intersection point is mainly influenced by the tip angle, independent of the measurement noise direction of the scanner. This is illustrated in Fig. 4b.

A performance evaluation test should be *easy*, *fast* and *representative* for the measurement task. Therefore a simple test method, based on a planar reference, is proposed in this paper.