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A performance test for a fringe projection scanner in various ambient light conditions

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Abstract

Optical triangulation based scanners have been widely used in industry, mainly for reverse engineering applications and freeform inspection tasks. Error contributions of these optical scanners include many influencing factors like surface quality and material properties of measurand, orientation and scan depth of sensors, ambient light changes, etc. This paper presents a performance evaluation test for a commercially available structured light scanner, under different ambient light conditions. The freeform reference standard developed by National Physical Laboratory is used to identify the influence of ambient light changes to the measurement accuracy.

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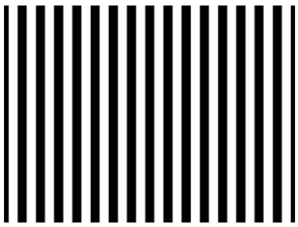
Keywords: Metrology; Optical scanner; Freeform; Ambient light

1. Introduction

Acquiring 3D point data from physical objects is increasingly being adopted in a variety of product development processes, such as quality control and inspection, reverse engineering and many other industrial fields. A variety of sensor technologies, such as the tactile method and optical techniques, have been developed to meet the requirement of surface digitization.

The existing tactile methods which are represented by CMMs (coordinate measuring machines) [1] have been widely used for industrial dimensional metrology, but the digitisation process is time-consuming. An alternative non-contact approach is represented by non-contact digitisation of surfaces based on optical triangulation techniques, for example laser scanner [2] and FPS (fringe projection scanner) [3].

The FPS method projects a grating stripes field which is modulated by a periodic function onto the surface of the objects (see Fig. 1). A DLP (digital light processing) projector has been commonly adopted for projecting phase stripe patterns owing to its easy availability, low cost, and high flexibility. The phase is used to describe the cycle distribution of grating field and the coordinates of points are obtained by calculating the phase of the fringe image. The phase of the grating stripes offset occurs due to variation in the height of the object surface. Through calibration of the scanner, camera coordinates are linked with coordinates in the grating stripes field. By capturing the shape of the projected intersection stripes with a digital camera, the coordinates of the points on the measuring surface are determined by triangulation. 3D coordinates of points can then be calculated by comparison of the relationship of phase shift offset and the height of surface.



(a) Original stripes

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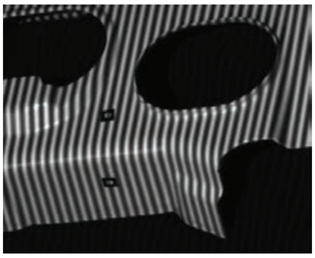
(b) Workpiece surface



(c) Projection grating

Fig. 1. FPS scanning process.

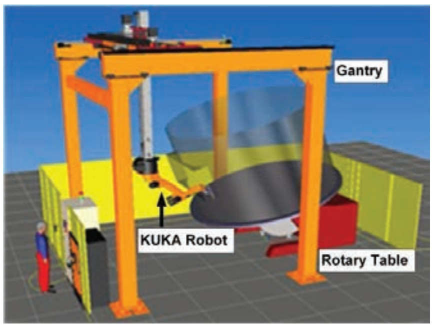
The main advantages of FPS, in comparison with conventional tactile probes, are the capability to measure contactless and to capture a large number of points in a short period of time. This makes them especially useful for digitising freeform surfaces and reverse engineering applications. The FPS method can directly measure the overall surface of the object by a single projection because the phase in the space is continuously distributed, which is a prominent advantage of the phase method. Additionally, a higher resolution can be achieved by using the "Phase-shifting" algorithm compared to the 1D and 2D triangulation sensors.

The most important disadvantages of FPSs, at this moment, are the limited measuring accuracy and low repeatability. Today state-of the-art FPSs can achieve the same order of magnitude of the accuracy in comparison with conventional tactical probes – but is greatly dependant opon the quality of surfaces to be measured.

The accuracy of FPSs is difficult to define because standardised procedures to evaluate CMM tactile probes are not appropriate for optical scanners due to different working principles. The increasing use of FPSs implies a growing need for reliable accuracy evaluation tests to analyse and improve the accuracy of the scanners. The quality of point clouds, obtained from laser line scanners, has been extensively investigated by Lartigue, Contriand and Bourdet [4,5]. Van Gestel, et al. [6] presented an extensive performance evaluation test for laser line scanners. In their work, the scanning depth, scanning angle with respect to the surface normal, thermal stability of scanner were investigated and tested. Bešić, et al. [7] introduced a method for improving the output of a CMM mounted laser line scanner for metrology applications.

The aim of this work is to investigate the influences of ambient lighting conditions on the measuring accuracy by using FPS in an AM (additive manufacturing) cell (Fig. 2). However, to the best of the author's knowledge, there is no relevant work that explores this type of problem. As controlled lighting conditions can be implemented to maintain consistency, it is necessary to study how the environmental lighting affects the measuring accuracy.

(a) AM cell exterior



(b) Schematic view

Fig. 2. AM cell.

2. Elements of the test

The commercially available FPS, GOM ATOS III Triple Scan (Fig. 3 (a)) is used for data acquisition and the FreeForm reference standard WP-150 (Fig. 3 (b)) is exploited to test the scanning accuracy in different ambient light conditions.

(a) GOM ATOS III Triple Scan