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Technical note

Extrinsic calibration of a conoscopic holography system integrated in a CMM

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ABSTRACT

In the present work, a procedure for extrinsic calibration of a 1D conoscopic holography sensor integrated in a CMM was developed, whereby it is possible to relate the coordinates of points captured by the sensor with the coordinate system of the machine. The procedure uses the information of the CMM error map to compensate the influence of these errors when associating the sensor measurements with the machine coordinate system. The calibration method was based on digitizing a test sphere and minimizing the error between the diameter of a least-squares fit of the digitized points and the value of its certified diameter. Results were compared for two test spheres of different diameter and material. To evaluate the efficacy of the calibration method, 3D distances between the spheres of a ball-plate were measured as well as several 3D geometrical features on a tailor-made test part. The tests carried out showed that the calibration method is independent of the type of test sphere used and that it is able to suitably compensate the positioning errors of the machine. Therefore, the calibration method proposed is applicable to integrate these type of sensors in CMMs and CNC machine tools with several controlled axes.

1. Introduction

The industrial application of non-contact digitizing systems has grown importantly in last years, covering a wide range of applications in the fields of dimensional metrology and reverse engineering. Apart from avoiding contact with the object to be measured and their progressive enhancement of precision, the main advantages of these systems in front of contact ones are their ability for digitizing small geometries and complex shapes with higher acquisition rates.

Today, many types of systems and technologies are used for non-contact scanning. According to the number of dimensions captured and the physical fundamentals for measuring, the guideline VDI/VDE 2617-6.2 [1] classifies these systems into 1D measuring sensors (point triangulation and conoscopic holography), 2D technologies (laser scanning and white-light interferometry) or 3D acquiring technologies (structured light).

In any case, the industrial use of any of these systems requires their integration in a machine (CNC machine tool, CMM, robot, articulated arm coordinate measuring machine, etc.) or in a production system. Apart from attaching the sensor to the machine, it is necessary to express measurements taken by the sensor with respect to the coordinate system of the machine or production system. For this purpose, a model should be provided to establish the relationships between the coordinate systems of the sensor and the machine, and a calibration procedure should be performed to quantify the relative parameters between them.

Calibration procedures are traditionally based on digitizing artefacts of known shape and dimensions, such as test spheres, cylinders, prisms, pyramids, ball-bars, ball-plates, etc. Moreover, calibration procedures should be simple, quick, precise and automatic for a successful application of any non-contact digitizing technique to dimensional metrology and industrial necessities. In this way, two types of calibration are found in literature for non-contact measuring systems: intrinsic and extrinsic calibration [2–6]. Intrinsic calibration involves correction of sensor internal parameters, whereas extrinsic calibration should provide the relationship between the coordinate systems of the sensor and the machine in which it is integrated. Commonly, commercial non-contact sensors are intrinsically calibrated by the manufacturer whereas extrinsic calibration must be performed specifically on the machine where they will be integrated.

Several approaches were dedicated to determine extrinsic calibration of non-contact sensors integrated in CMMs and CNC machine tools. The principal differences among them were about the type of sensor considered as well as the artefacts, algorithms and procedures used to carry out calibration.

The main types of non-contact sensors integrated in machines include laser light sensors 2D [2,3,[5],7–9], point triangulation 1D [4,10,[6]], stereo photogrammetry 3D [11] or multi-sensor systems [[5],[9]]. In most cases, these sensors were integrated in CMMs [2–8,10,11] while a minority took part of special developed measuring machines [9]. With regard to calibration artefacts, most authors used single spheres

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