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CNC centralized control for digitizing freeform surfaces by means of a conoscopic holography sensor integrated in a machining centre

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ABSTRACT

This paper presents the integration of a conoscopic holography sensor (CH) in a machining centre (MC) by means of a centralized control on the machine's CNC (*CNC centralized control*). Besides the installation and extrinsic calibration of the sensor, the primary focus is the automation of the freeform digitizing process on the MC itself. To overcome the usual lack of compatibility between the respective interfaces of the CNC machine and the non-contact sensor, a system was developed to centralize the control intelligence on the machine's own CNC, enabling digitizing operations to be performed directly with the execution of an NC subroutine. In addition, three digitizing strategies are proposed: *Non-Adaptive*, *Adaptive* and *Predictive-Adaptive*. These require no planning tools or off-line programming prior to the digitizing process. The effectiveness of the extrinsic calibration method was validated by measuring a certified *ballbar, and* the integrated measuring system was checked by comparing the metrological results obtained by digitizing a freeform surface with those obtained by a CMM contact probe and with the CAD model used for machining the surface.

1. Introduction

Inspection activities are of vital importance in today's industry to ensure that manufactured components meet design specifications. Inspection is usually carried out on CMM machines, owing to their high precision and measuring capacity. These machines require a considerable investment, however, and the need to move the component from the machine tool to the CMM leads to loss of precision and productivity.

To overcome these drawbacks, techniques have been developed to enable components to be measured directly on the same machine that manufactured them (On-Machine Measurement or OMM). In this way, production machines may be used for measurement purposes similarly to CMM contact probes, though metrological behaviour tends to be inferior.

Although many manufactured parts are designed using a combination of different primitive shapes (planes, cylinders, cones, spheres, etc.), more and more industrial sectors (automotive, aeronautics, energy, etc.) are demanding high-quality components that incorporate freeform surfaces. These characteristics, and even the size of the surface, mean that dimensional inspection requires data capture from a great number of points.

Measurement of freeform surfaces using CMMs is currently performed using algorithms of form deviation evaluation based on probe radius correction, which improves accuracy compared to methods based on direct use of nominal points [1].

Despite their precision, contact probes are not suitable for freeform surface digitizing in machine tools. Their main failings are their low data point capture rate, likely accessibility problems, the need for probe tip radius correction, and the possibility of errors caused by tip wear, stylus bending, and even surface deformation at contact points [2], especially when digitizing soft materials.

Under such conditions, non-contact scanning techniques seem to be an advantageous alternative to contact methods since they allow for high acquisition rates, better accessibility conditions and, in many cases, similar levels of accuracy. Even so, the use of commercial non-contact measurement systems for OMM applications is still very limited. Many research works have studied the integration of non-contact sensors in production machines [3–5], but they have been primarily concerned with the installation of the sensor and calibration of the machine-sensor assembly, and have not tended to deal with the automation required to synchronize the running of both systems. A major difficulty to overcome is the considerable heterogeneity between the respective controllers of CNC machines and non-contact sensors, which renders the direct connection of such equipment for the synchronized operation of OMM tasks almost impossible.

Even if the interfaces were compatible, the majority of CNC

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