Influence of scanning strategies on measuring and surface digitising by means of a conoscopic holography sensor integrated in a machining centre

Gonzalo Valiño*, J. Carlos Rico, Pablo Zapico and Pedro Fernández

Department of Construction and Manufacturing Engineering,
University of Oviedo,
Campus of Gijón,
33203 Gijón, Spain
Email: gvr@uniovi.es
Email: jcarlosr@uniovi.es
Email: zapicopablo@uniovi.es
Email: pedrofa@uniovi.es
*Corresponding author

Abstract: A conoscopic holography sensor (CH) integrated in a machining centre was used to analyse how the scanning strategy affects distance measurements between planes and to the reconstruction of a digitised surface. Distance measurement tests were conducted on a stepped specimen whereas the surface reconstruction was studied on a cylindrical surface. Two different scanning strategies were compared. In the first, the height position of the sensor kept constant along the surface scanning so that all the points were located at different positions within the sensor depth of field (DOF). In the second strategy, the sensor was continuously adjusted describing a trajectory equidistant to the surface so that all the points were acquired at a same distance within the DOF. Both strategies were compared by the discrepancies between measurements taken by the CH sensor and those obtained by a touch probe. Some recommendations are provided for distance measurement and surface reconstruction.

Keywords: conoscopic holography; scanning strategy; depth of field; DOF; measuring and surface digitising; on-machine measurement.

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Biographical notes: Gonzalo Valiño received his MSc in Industrial Engineering and the PhD from the University of Oviedo (Spain) in 1994 and 2004, respectively. He worked as Industrial Engineer for two companies in the metalworking sector for two and a half years until he entered the University of Oviedo in 1998 as an Associate Lecturer. He reached the rank of Senior Lecturer in 1996 and has been working for the Department of Construction and Manufacturing Engineering at the University of Oviedo since then. He developed different research activities in the field of automation and planning

of manufacturing processes. His current area of interest is focused on the implementation and integration of contact and non-contact inspection and digitising sensors in different equipment and production machines.

J. Carlos Rico received his MSc in Industrial Engineering and PhD from the University of Oviedo (Spain) in 1985 and 1990, respectively. Since 1996, he works as a Full Professor for the Department of Construction and Manufacturing Engineering at the University of Oviedo. In his research activity, he worked in the field of automation and manufacturing process planning. His current area of interest is focused on the implementation and integration of contact and non-contact inspection and scanning sensors in different equipment and production machines.

Pablo Zapico received his MSc in Industrial Engineering and MSc in Mechatronic Engineering from the University of Oviedo (Spain) in 2012 and 2014, respectively. In 2014, he obtained a 'Severo Ochoa' grant for research and teaching. He is currently developing a PhD thesis in the field of integration of conoscopic holography in production CNC machines and CMMs applied to non-contact inspection and digitising.

Pedro Fernández received his MSc in Industrial Engineering and PhD from the University of Oviedo (Spain) in 2004 and 2011, respectively. Since 2011, he works as an Associate Professor for the Department of Construction and Manufacturing Engineering at the University of Oviedo. His research activity focuses on the field of digitising systems, reverse engineering and digitising process planning. His current areas of interest are related to the application of inspection and digitising non-contact sensors to on-machine industrial measurement.

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1 Introduction

Industrial use of commercial scanners like non-contact digitising systems has grown significantly in recent years with a wide range of applications that go from dimensional metrology to reverse engineering (Blais, 2004; Sansoni et al., 2009). Apart from avoiding contact with the object to be measured, the main advantages over contact systems are the ability to capture small geometries and complex shapes as well as the high speed for acquisition of points. Additionally, portability of non-contact systems makes it possible to install them in different equipment such as coordinate measuring machines (CMM), coordinate measuring arms, machine tools or other production systems, which certainly favours their industrial application.

Despite these advantages, commercial non-contact scanners are usually less accurate than the traditional contact-type methods, since their accuracy depends strongly on the relative position and orientation of the sensor with regard to the digitised part, the configuration parameters of the sensor, the part geometry, the optical properties of material, the surface roughness, etc.

Currently there exist numerous non-contact techniques for surface digitising, such as those based on triangulation laser, which have been more deeply analysed and spread every day. Muralikrishnan et al. (2012) established bounds on errors when measuring simple linear dimensions and Popov et al. (2010) investigated the types of scanning errors and proposed a methodology to improve the performance of a laser scanner in terms of accuracy. Feng et al. (2001) and Isheil et al. (2011) examined the effect of scan distance and beam incident angle on the random and systematic errors of the scanner and also provided models for compensating the measurement errors. Vukašinović et al. (2010, 2012) used a triangulation laser scanner installed in a CNC platform to analyse the influence of the colour of a measured surface, the distance between the surface and the sensor and the angle of measurement. They considered different quality indicators of measurement results, such as the number of points captured by the sensor or the intensity of the reflected light beam for different slope angles. The highest intensity was obtained for a light source perpendicular to the scanned surface but rapidly decreased for other angles. Regarding colour, the best measurement results were obtained for surfaces with a good diffuse reflection at the wavelength of the laser sensor used. Moreover, the results showed that the feasibility for measuring small details decreased as distance increased.

The study presented by Bin et al. (2014) used a laser sensor installed in a 5-axes machining centre (MC) to analyse the effects of position and orientation on the laser measurement of free-form surfaces. To improve the measurement accuracy, a measurement strategy that considered the position and orientation of the sensor and a semi-quantitative error-compensation model based on geometrical optics was proposed. Manorathna et al. (2014) presented a set of performance evaluation tests for a 3D laser scanner attached to a 6-axes robot. The scanner was evaluated under operating conditions such as different surface reflectivity, view angle, surface roughness and standoff distance. The best working range was established and the regions of noise and missing data were identified and quantified.

Apart from these works related to laser triangulation sensors, the performance of other scanning technologies has not been fully described yet. This is the case of conoscopic holography (CH), an interferometric technique based on the double refractive property of birefringent crystals. It was first described by Sirat and Psaltis (1985) and patented by Optimet Optical Metrology LTD. Malet and Sirat (1998) stated that the performance of a conoscopic system may be described by the quartet of precision, depth of field (DOF), speed and transverse resolution. Furthermore, many advantages of CH in front of laser triangulation were reported by Sirat et al. (2005) such as better accuracy and repeatability, good behaviour for a wide variety of materials, ability to digitise steep sloped surfaces and feasibility for combining the sensor with different lenses to be adapted to various depths of field. Finally, being a collinear system allows for accessing to complex geometries such as holes or narrow cavities, by using simple devices for light redirection.

All these characteristics demonstrate the feasibility of CH systems for being applied to different fields of industry, including quality assessment, reverse engineering or in-process inspection. Nevertheless, CH digitising quality may be affected by a lot of factors similarly to other optical techniques. This led researchers to work on analysing the performance of CH sensors under different scanning conditions. The ability of CH for digitising sharply sloped surfaces was highlighted by Ko and Park (2006) when they compared the capabilities of triangulation, CH and interferometry methods for accurate