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Metrological evaluation of Microsoft Kinect and Asus Xtion sensors

H. Gonzalez-Jorge [a,*], B. Riveiro [b], E. Vazquez-Fernandez [c], J. Martínez-Sánchez [a], P. Arias [a]

[a] School of Mining Engineering, University of Vigo. Rúa Maxwell s/n, Campus Lagoas-Marcosende, 36310 Vigo, Spain
[b] School of Industrial Engineering, University of Vigo. Rúa Maxwell s/n, Campus Lagoas-Marcosende, 36310 Vigo, Spain
[c] Gradiant – Galician R&D Center in Advanced Telecommunications, Edificio CITEXVI, Local 14, Campus Lagoas-Marcosende, 36310 Vigo, Spain

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ABSTRACT

In recent months Kinect and Xtion sensors appear massively at the entertainment market. In parallel, many developers show engineering applications of the system related with their 3D imaging possibilities. In this work a metrological geometric verification of the systems is performed using a standard artifact which consists of five delrin spheres and seven aluminum cubes. Accuracy and precision tests show non-dependence with the type of sensor (two Kinect and one Xtion are used for the experiment) or with the incident angle between the standard artifact and the sensor (45°, 90° and 135°). Precision decreases with range according to a second order polynomial equation. Ranges larger than 7 m cannot provide any measurement. Accuracy data change from 5 mm to −15 mm for 1 m range and from 5 mm to −25 mm for 2 m range. Precision data change from 1 mm to 6 mm for 1 m range and from 4 mm to 14 mm for 2 m range.

The results confirm that these sensors can be used in many engineering applications when the measurement range is short and accuracy requirements are not very strict.

1. Introduction

Laser scanner is an engineering instrument which is used to digitalize a 3D physical object [1,2]. The 3D laser equipment uses different sensor technologies depending on the requirements of the measurement. Triangulation scanners are typically used for small ranges and high precision (i.e. fraction of millimetre), phase shift scanners for intermediate ranges and precisions (i.e. 1–3 mm) and time of flight scanners for high ranges and lower precisions (i.e. 2–10 mm) [3–8].

The triangulation 3D laser scanners shine a laser on the surface of the object and exploit a camera to look for the location of the laser dot. Depending on how far away the laser strikes the surface, the laser dot appears at different places in the camera sensor. This technique is called triangulation because the laser dot, the camera and the laser emitter form a triangle. The length of one side of the triangle (distance between the camera and the laser emitter) is known. The angle of the laser emitter corner is also known. The angle of the camera corner can be determined by looking at the location of the laser dot in the field of view of the camera. These three pieces of information determine the shape and size of the triangle and gives the location of the laser dot corner of the triangle. In most cases a laser pattern, instead of a single dot, is swept across the object to speed up the acquisition process.

Scanners based on phase shift measurements use a continuous laser wave as the carrier for a modulated signal. The phases of the emitted and received signals are compared and related with the range measurement. Scanners based on the principle of time of flight emit a short light pulse, which, after reflection by the surface of the object of study, is focused by the photodetector. The distance is evaluated through the time delay of the laser pulse while traveling between the point of emission and the surface scanned.

* Corresponding author. Tel.: +34 986818752.
E-mail address: higiniog@uvigo.es (H. Gonzalez-Jorge).

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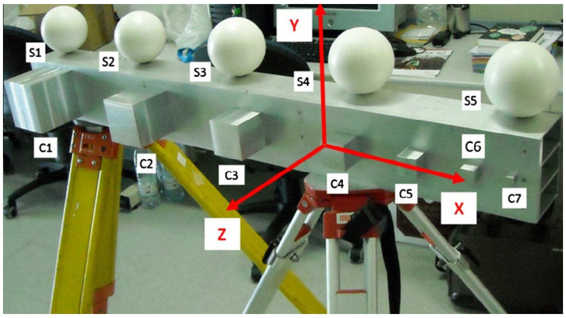

Fig. 1. Standard artifact.

Table 1
Length L_{ss} and standard deviation ΔL_{ss} between the centers of the spheres. Data is obtained using the coordinate measuring machine Mitutoyo Euroc apex 12010.

Spheres	L_{ss} (m)	ΔL_{ss} (m)
S1–S2	0.25020	0.00008
S1–S3	0.50014	0.00007
S1–S4	0.75017	0.00014
S1–S5	1.00039	0.00006

All these techniques generate a point cloud which represents the shape of the scanned object. By using special software (i.e. Polyworks, Geomagic), the point cloud data can be processed and converted into a polygonal representation of the object which has been scanned.

Microsoft Kinect and Asus Xtion are becoming important 3D sensors. These systems combine structure light with two classic computer vision techniques: depth from focus and depth from stereo. It uses infrared laser lighting with a speckle pattern. The depth map is constructed by analyzing a speckle pattern of infrared laser light. They are receiving a lot of attention thanks to a rapid human pose recognition system developed on top of 3D measurement. The low cost, reliability and speed of the measurement promises to make Kinect and Xtion one of the primary 3D measuring devices for indoor robotics and mapping, 3D scene reconstruction and object recognition [9–12]. The use of sensors as Microsoft Kinect and Asus Xtion in applications beyond entertainment is of great interest, although the technical characteristics of the system must be studied in detail to ensure its application in areas where the geometric characteristics of the object could be important. This manuscript presents a metrological study of the Kinect and Xtion sensors using a dimensional standard artifact. Such artifact was previously certified using a coordinate measuring machine with traceability to length standard. Two different Kinect sensors are used for this study to test the manufacturing quality assessment of this type of systems.

Fig. 2. Microsoft Kinect (top) and Asus Xtion (bottom).

2. Materials and methods

2.1. Standard artifact

The main parts of the standard artifact are five delrin spheres and an aluminum block with seven cubes of different dimensions. The aluminum blocks are manufacture using a precise CNC machine [13–15]. Fig. 1 shows a photograph of the object. The spheres present a nominal diameter of 100 mm and the edges of the cubes range between 100 mm and 10 mm. All the elements are glued and screwed. Tables 1 and 2 show the main geometric characteristics of the standard artifact. The system is portable and allows the comparison of laser scanners of different technical characteristics. The standard is calibrated in AIMEN Technological Centre (Vigo, Spain) which is ENAC accredited for dimensional measurements according the ISO 17025:2005. The calibration procedure uses a precision coordinate measurement machine.

2.2. Laser scanners

Kinect (Fig. 2) is a sensing device developed by Microsoft for a Xbox video game console. It enables users the interaction with Xbox without the need of special game controller, through a natural user interface using gestures

Table 2
Length of cubes in the three main axis. Data is obtained using the coordinate measuring machine Mitutoyo Euroc apex 12010.

Cube	L_{sx} (m)	ΔL_{sx} (m)	L_{sy} (m)	ΔL_{sy} (m)	L_{sz} (m)	ΔL_{ss} (m)
C1	0.10003	<0.00002	0.10007	<0.00002	0.10002	<0.00002
C2	0.08000	<0.00002	0.08005	<0.00002	0.07998	<0.00002
C3	0.06002	<0.00002	0.06001	<0.00002	0.05998	<0.00002
C4	0.03998	<0.00002	0.04003	<0.00002	0.04004	<0.00002
C5	0.03005	<0.00002	0.03000	<0.00002	0.03001	<0.00002
C6	0.02002	<0.00002	0.01997	<0.00002	0.02001	<0.00002
C7	0.01003	<0.00002	0.01001	<0.00002	0.00999	<0.00002