TESTING THE CAPABILITIES OF THE THREE-SPHERES ALIGNMENT METHOD FOR LASER TRIANGULATION SENSORS

CONFERENCE PAPER · APRIL 2008

4 AUTHORS:


Susana Martínez
Universidad de León
37 PUBLICATIONS **81** CITATIONS


Eduardo Cuesta
University of Oviedo
69 PUBLICATIONS **115** CITATIONS


J. Barreiro
Universidad de León
95 PUBLICATIONS **228** CITATIONS


Pedro Fernández
University of Oviedo
32 PUBLICATIONS **26** CITATIONS

6th International DAAAM Baltic Conference
"INDUSTRIAL ENGINEERING -
24-26 April 2008, Tallinn, Estonia

TESTING THE CAPABILITIES OF THE THREE-SPHERES ALIGNMENT METHOD FOR LASER TRIANGULATION SENSORS

Martínez, S.; Cuesta, E.; Barreiro, J. & Fernández, P.

Abstract: *This paper studies the suitability of the 3-spheres conventional alignment method located in the test part. Firstly, the three spheres are measured by contact scanning using a touch stylus probe (trigger probe) with the highest precision. Secondly, scanning with a laser triangulation sensor is used applying different strategies. Then, deviations among the point clouds of the digitized spheres generated with laser scanning are analyzed.*

The obtained results not only show the importance that a right choice of the part reference system has, but also the size and location of the reference spheres with respect to the test part. These aspects affect the inspection times and measuring errors directly.

Keywords: Laser scanning, dimensional control, reference system

1. INTRODUCTION

Nowadays, there are more and more works dedicated to the improvement of the production processes. Among the activities included in such processes, there are the reduction of times and costs using measuring systems without contact, and especially the laser scanning systems. Although this technology started initially to carry out activities of Reverse Engineering, in those where a product is designed capturing the shape of a real part, it is increasingly being incorporated to other fields as the dimensional control of industrial parts. This measuring systems growth is justified with its advantages, like the reduction of costs and their benefits (speed in the capture of points, high number of points, quality of the captured points, etc.) [1]. Today, companies are forced to manufacture their products with high precisions and low lead times, and in some cases, products have large dimensions and complex surfaces difficult to inspect dimensionally by other traditional methods.

The analysis of the suitability of laser scanning in dimensional control activities requires developing tests with pattern parts. These patterns must be well-known in dimensional point of view and with good optical and geometric characteristics [2] to allow finding the errors that laser sensor adds with respect to contact system. However, the influence of geometry, the environmental light or the part roughness are decisive in this analysis [3,4]. Before making these analyses, to solve the problem of getting an alignment among both techniques with the minimum possible error is necessary. This alignment depends on the resources used. When a multisensory Coordinated Measuring Machine (CMM) that incorporates a triangulation laser sensor and a touch trigger probe is used, it is habitual to work with both systems in an independent way. In this case, all the obtained points (with laser and contact) are referred to the machine home and then the change to part origin is carried out (in some singular/s feature/s).

For this research, both clouds of points must be referred to the same reference system with the minimum possible error.

This is important not only when it is necessary to carry out several partial scans with different part positions but also, like in this study, where the part does not move but it should be digitized by the two scanning systems (for later comparison).
Several methods exist to perform these alignments. One of the most common and simple method consists on placing three reference spheres that are digitized at the same time that the pattern surfaces. The surfaces of the spheres are reconstructed and their centers are used to establish a unique reference system. With the purpose of making contact/laser comparisons in the most precise way, several tests were carried out. The goal of these tests was to evaluate the differences (advantages and disadvantages) among the different scanning strategies.
A CMM has been used for the capture of data (Global model of Brown&Sharpe) using two types of sensor:
- For the contact scanning, a PH10MQ head of Renishaw with a touch trigger probe of 2 mm of diameter tip.
- For the laser scanning, a laser triangulation sensor (LTS, LC-50 of Metris © model) on the same head of the CMM.
All the scanning parameters (intensity, number of captured points, environmental light, distances of focus,...) were kept constant for the digitalization of each sphere, and only the strategy and the parameters related exclusively with the reference system have been varied:
- The spheres size.
- The spheres location with regard to the surfaces to digitize.
- The number and the orientation of the different scans.
Different software applications were used, as METRIS SCAN (the laser sensor native application), CATIA v5 and Geomagic Studio v9. These two last applications were used to reconstruct the surfaces. Also, Geomagic Qualify v8 application was used to perform the comparisons among the surfaces.

2. DEVELOPMENT OF TESTS

2.1 Initial scanning and existent problems

Tests started with a series of pattern parts with appropriate optical properties. Three precision spheres were placed over them (initially with Ø8,5 mm). It was necessary to recover them with a white painting spray to be able to digitize the spheres with the laser system with guarantees of high number of points. The precision loss that this spray adds was reduced with successive repetitions on the same ones (in the case of the laser) and adding contact scanning.
The procedure used for the spheres laser scanning is usually applied in the modern industry. The first step is a scan of each sphere with the position probe at A0B0, followed by the reconstruction of them with the obtained points. Then, the normal scan of the parts according to the most favorable orientation is made.

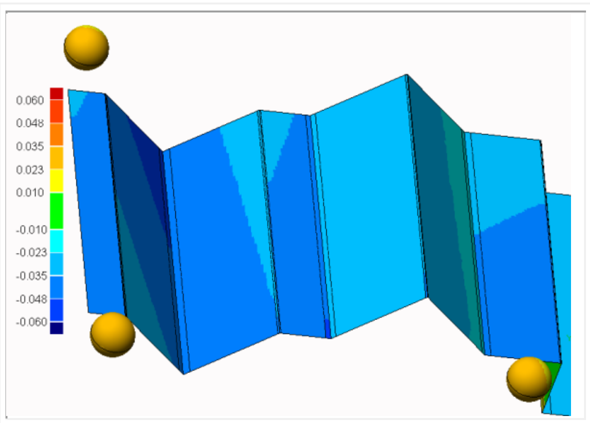

Fig. 1. Comparison among reconstructed surfaces by contact and non contact system (CATIA)

The software Geomagic Qualify v8 was used to make the comparison of the surfaces. This program requires choosing one of the surfaces as “Reference” and the other one as “Test”. The surface obtained by means of the contact system was chosen as “Reference” to make the comparison with the surface obtained by means of the laser system. In order to align the two surfaces, the center of each of the three spheres located in the digitized parts by contact is made correspond with the center of the digitized spheres by laser. Figure 1 is a 3D resultant comparison between both methods. It can be appreciated that all the “Test” surfaces (laser) have negative Z coordinate with regard to the “Reference” surfaces (by contact). The color of the spheres indicates that they have a higher diameter than the equivalent in the “Reference” obtained by contact. The analysis of the deviation between the “Test” surfaces and the “Reference” surfaces leads to the conclusion that a uniform value couldn’t be established for the whole part. This fact led to think about the precision of the adjustment among the spheres obtained by contact and those obtained by laser, because if the laser system gives different coordinates (habitually according to Z) with respect to those from the contact system, this alignment might be wrong. This effect was analyzed in a previous work [5], where the center position coordinates of a reference sphere were determined by adding the difference between the radii of the obtained spheres to the *z* coordinate of the sphere center. In other work [6] the sphere center was determined slicing the sphere surface into several parallel and consecutive slices. Therefore, a new test to determine the deviation between the center position of the digitized spheres by laser and by contact (fig. 2) is necessary.

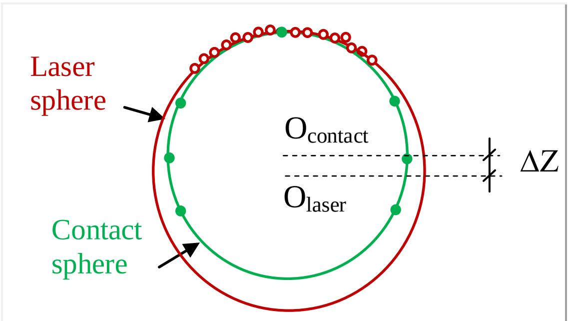

Fig. 2. Deviations between spheres.

2.2 Change in the number and orientation of the scans.

The procedure for the capture of points by contact did not varied, because more points than the necessary ones were captured to define perfectly a sphere (25 points). This digitized by contact offers a higher guarantee of precision and repeatability, so that it has been taken as a base for later comparisons.

In the laser scanning, the differences using a single scan orientation or several scans (different orientations) on each sphere have been studied and analyzed. The obtained results show that both the spheres radius and their centers Z coordinate change depending on whether only one point-cloud is obtained at 0º, azimuthally, or more point-clouds (3 or 5) with different angles are used.

The number of scans showed in fig.3, with 1, 3 and 5 different orientations, were chosen for accessibility reasons mainly:

No. of Scans	**Orientations**
1	A0B0 (thus, only azimuthally)
3	A0B0 + A60B0 + A60B90
5	A0B0 + A60B0 + A60B90 + A60B180 + A60B-90 (azimuthally & 4 cardinals orientations)

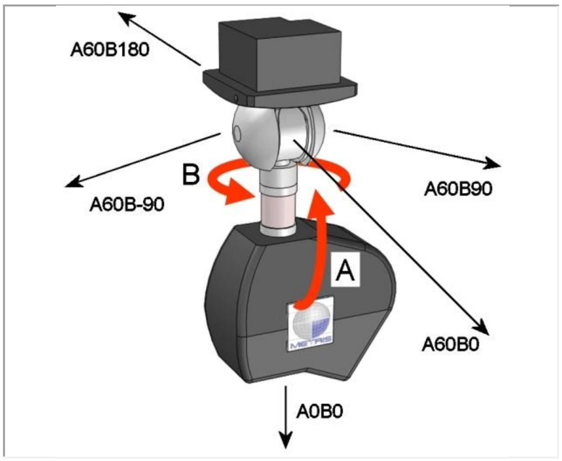

Fig. 3. Laser head orientations

Besides, three different CAD softwares were used:

- Metris Scan (LTS sensor native software)
- Catia v5 r17

- Geomagic Studio v9

Test Results:

- With regard to the point-clouds obtained (laser or contact systems) to build the spheres, the software used is not a concern. The differences are about 3 µm using one or another system, which is not considered out of range.
- The radius of the spheres obtained decreases when the spheres are built using more scans. The difference between one or five scans is about 22 µm (fig. 4).

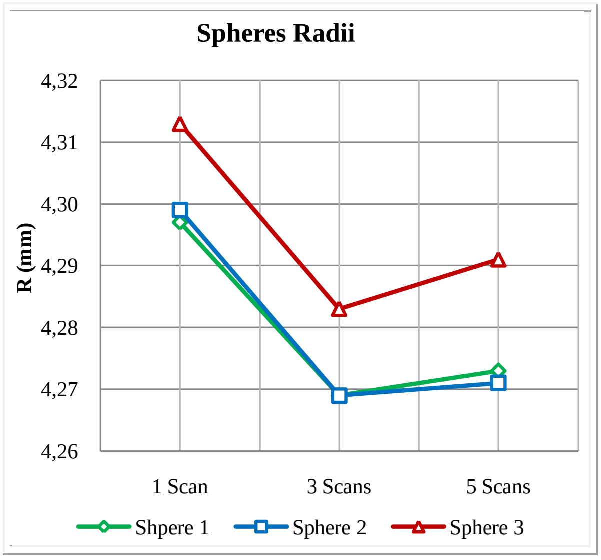

Fig. 4. Spheres radius evolution with the increase in the number of scans.

- The radius of the spheres is closer to the real value (by contact) when more scans are used.

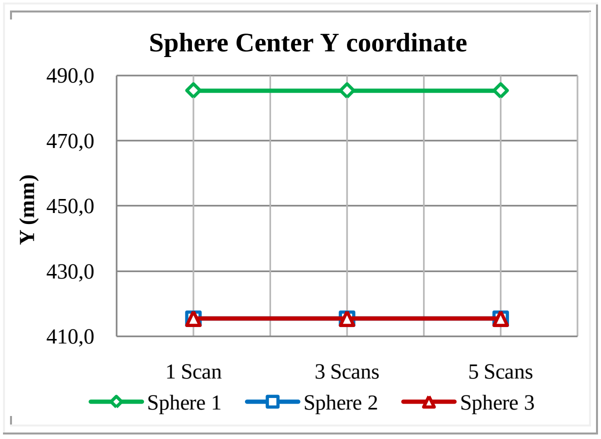

Fig. 5. Center Y coordinate evolution in a part with the increase in the number of scans.

- The X and Y coordinates remain constant with the increase of scans (fig. 5).
- The center Z coordinate of the sphere is the one that most changes suffer when the number of scan orientations is increased. In all cases, the trend would be interpreted as if the spheres were located in a superior Z coordinate with the increase in the number of scans. The difference between one and five scans is around 35 µm (fig. 6).

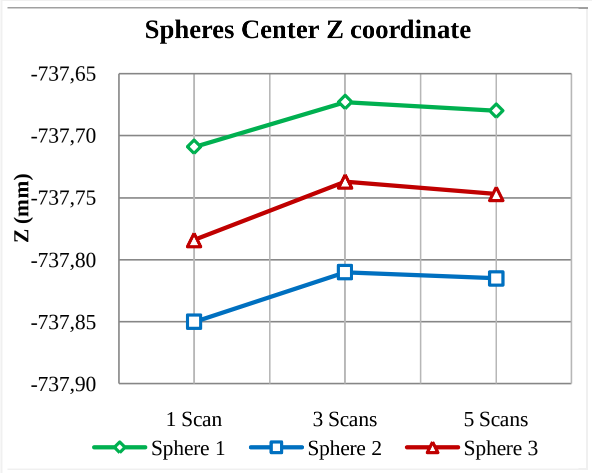

Fig. 6. Evolution of spheres center Z coordinate when the number of scans is increased.

- If the location of the 3-spheres does not constitute a perfect equilateral triangle, the selection order of the spheres to scan also affects the final result (Fig. 7).

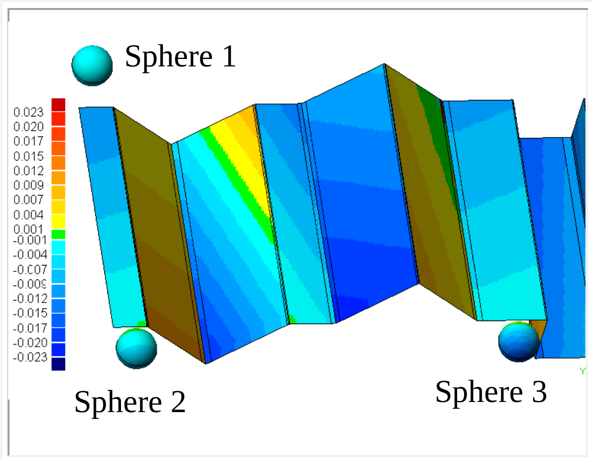

Fig. 7. Change of the spheres adjustment. The sphere "1" has been adjusted firstly.

The sphere selected in first place will have the best adjustment, and the deviation will increase when moving away from it (rest of spheres).

2.3 Change of the spheres diameter and location

The reference system was changed taking into account the carried out observations. The diameter of spheres was increased (Ø20,5 mm) and their position were changed with regard to the parts.

A fixture applicable to all the pattern parts was used. This fixture included three new reference spheres positioned farther away from the part and always fixed in the same position.

Test Results:

• As it was expected, increasing the diameter of the spheres the roundness error decreases. The initial values were under 30 µm. These values decreased in half or even less (8 µm) with the biggest spheres. The roundness errors are probably due to the white spray used to eliminate the laser reflections over the shiny surface of the spheres. Obviously, one of the most important conclusions obtained with this new test was that the relative error decreased very much. A roundness error of 20 µm in a Ø8,5 mm sphere corresponds to a higher relative error than a roundness error of 12 µm in a Ø20,6 mm sphere.

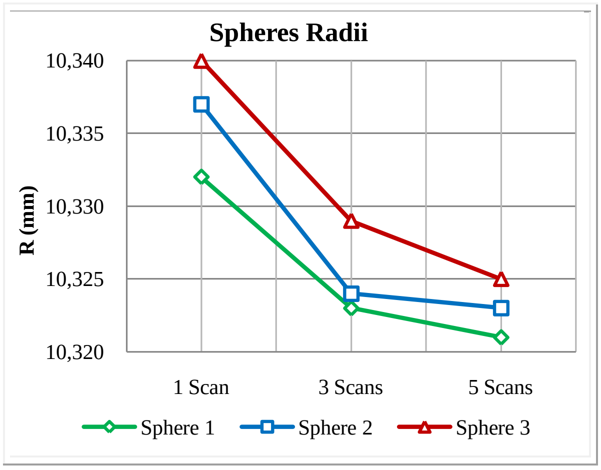

Fig. 8. Spheres radius evolution with the increase in the number of scans.

Additionally, although there is still a difference between the radii obtained with one or five scans, this difference decreases now around 12 µm (fig. 8).

• The variation of the center Z coordinate for each sphere is now much smaller than before. The difference between one and five orientations is around 15 µm, closer to the value obtained by the contact system.

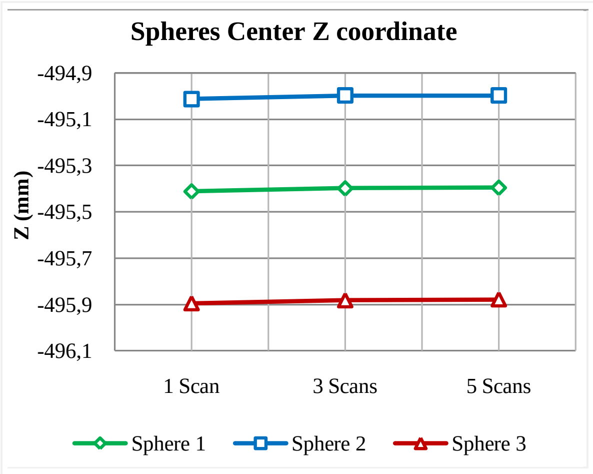

Fig. 9. Spheres Z coordinate evolution with the increase of the number of scans.

This observation allows to affirm that the number of necessary scans for a precise reconstruction of the reference spheres and for the later alignment can be reduced when increasing the diameter of the spheres.

3. CONCLUSIONS

In order of the results obtained in the tests, the following conclusions can be stated:

• The best way to align and to reference the parts consists in using spheres of large diameter separated sufficiently, so that the effect of the alignment is the same for the whole part to digitize.

• In order to reduce the operation time, the number of orientations can be decreased increasing the diameter of the spheres. The reduction in the number of orientations is even more evident when the Z coordinate study is the most important aspect to test.

• To maintain the same order in the selection of the reference spheres until finishing the alignment is always important for the comparative among surfaces.

4. ACKNOWLEDGEMENTS

This paper is part of the results of a Research Project supported by the Spanish Comisión Interministerial de Ciencia y Tecnología (about automated planning with laser scanning sensor, ref. DPI2004-03517). Also, this work was supported by the Spanish R2-TAF initiative through a researcher mobility grant.

5. REFERENCES

[1] Seokbae, S.; Hyunpung, P.; Kwan, H.L. Automated laser scanning system for reverse engineering and inspection. *Intern. Journal of Machine Tools & Manufacturing.* 2002, **42**, 889-897.

[2] Cuesta, E.; Fernández, P.; Rico, J.C.; Álvarez, B.; Blanco, D. Aplicaciones Metrológicas y de Ingeniería Inversa de los láseres por triangulación. *Deform. Met.* 2005, **284**, 59-73.

[3] Cuesta, E.; García, A.; Álvarez, B.; Valiño, G.; Rico, J.C. Análisis de la influencia del acabado superficial en la calidad del digitalizado con sensores láser por triangulación. *Proc. of the 2nd Manuf. Eng. Soc. Intern. Conf. (CISIF-MESIC´07)* (CD-ROM). 2007.

[4] Blanco, D.; Garcia, M.; Fernandez, P.; Mateos, S.; Suarez, C.M. Evaluación de la influencia de la iluminación en el digitalizado por triangulación láser: aplicación a una fuente de luz halógena. *Proc. of the 1st Manuf. Eng. Soc. Intern. Conf. (CISIF-MESIC´05)*(CD-ROM). 2005.

[5] Hsi-Yung, F.; Yixin, L.; Fengfeng, X. Analysis of digitizing errors of a laser scanning system. *Jour. of the Inter. Soc. for Prec. Eng. and Nanotechn.* 2001, **25,** 185-191

[6] Chenggang, C.; Jun, N. A ball-target-based extrinsic calibration technique for high-accuracy 3-D metrology using off-the-shelf laser-stripe sensors. *Jour. of the Inter. Soc. for Prec. Eng. and Nanot.* 2000, **24,** 210-219

6. CORRESPONDING ADDRESS

Susana Martínez Pellitero
University of León.
E.I.Industrial e Informática. Campus de Vegazana, 24071. León, Spain
Phone: +34 987291000 ext:5357,
Fax: +34 987291930
E-mail: susana.martinez@unileon.es