Development of Rotation Scanner, Testing of Laser Scanners

Bronislav KOSKA, Tomáš KŘEMEN, Martin ŠTRONER, Jiří POSPÍŠIL and Milan KAŠPAR, Czech Republic

Key words: laser scanning, digital camera, rotating platform, point cloud.

SUMMARY

Assoc. Prof. Jiří Pospíšil (K154, FCE, CTU) has obtained grant GA ČR 103/02/0357 „Modern Optoelectronic Methods of Measuring Surfaces' Topography“ for years 2002-04. The 3D laser scanning system LORS (Laser and Optic Rotating Scanner) is developed, and a testing of a terrestrial laser scanning precision is carried out as a part of this grant.

LORS was designed for scanning of small objects. It consists of three basic parts. There is a calibrated digital camera mounted on a theodolite, the laser module, which forms a laser plane, and a rotating platform. The rotating platform has a constant rotation velocity. The laser plane crosses a measured object and creates a laser mark. The 3D point is created by intersection of the laser mark and an optic line. The optic line is defined by corrected image coordinates of the laser mark.

The calibration of the digital camera on the theodolite was designed and realized. The equations for determination of 3D coordinates of points on a scanned object were also derived. The improvement of the laser plane quality was made on the base of initial experiments. Precision tests are now being held. The system and its precision seem to be suitable for scanning of small archaeological artifacts.

The testing of properties of terrestrial laser scanning systems is being held to determine limits of practical using. The tests to verify influence of different types of materials under various angles on measurement and influence of high angles of impact on scanning precision were made. The commercially available laser scanning systems based on space polar method were tested and compared.

Development of Rotation Scanner, Testing of Laser Scanners

Bronislav KOSKA, Tomáš KŘEMEN, Martin ŠTRONER, Jiří POSPÍŠIL and Milan KAŠPAR, Czech Republic

1. 3D LASER SCANNING SYSTEM LORS

1.1 Presentation of the System LORS

Assoc. Prof. Jiří Pospíšil (Department of Special Geodesy, Faculty of Civil Engineering, Czech Technical University in Prague) has obtained grant GA ČR Grant No. 103/02/0357 "Modern Optoelectronic Methods of Measuring Surfaces Topography" for years 2002-04. The 3D laser scanning system LORS (Laser and Optic Rotating Scanner) is developed as a part of this grant. An operative prototype has been already developed. The system seems to be suitable for scanning of small archaeological artifacts.

1.2 Hardware Solution of the System LORS

The system is composed of three hardware components. There is a digital camera, the laser module, which forms a laser plane, and a rotating platform.

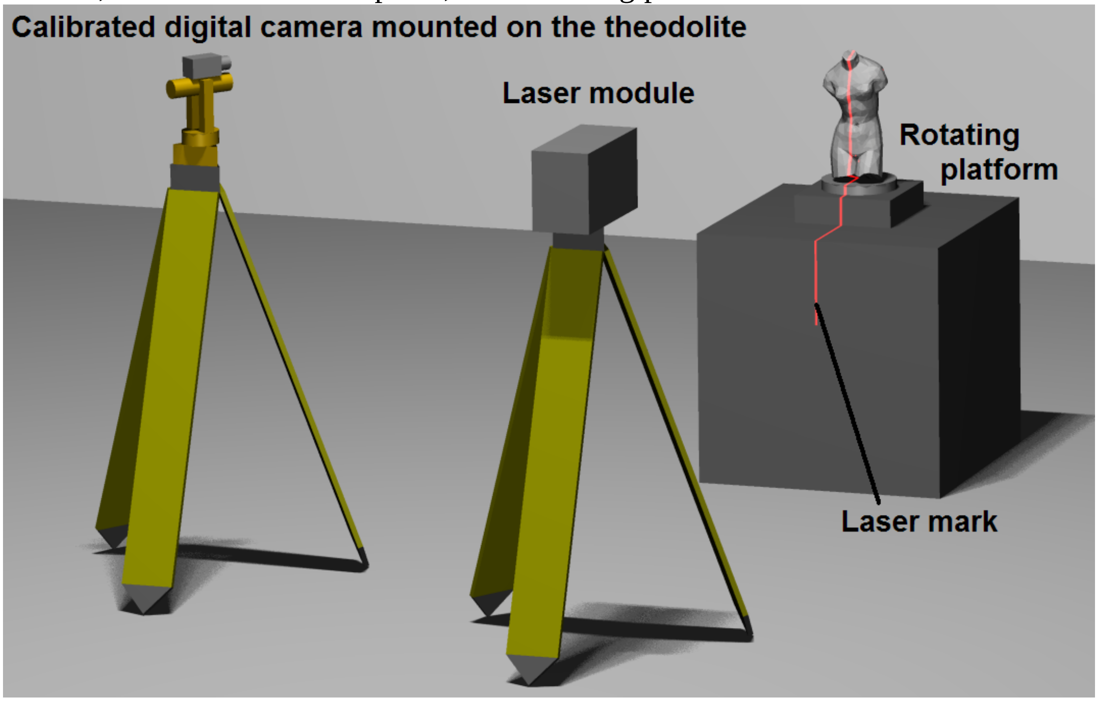

Figure 1: Model of the system LORS

The calibration of the digital camera on a theodolite was designed and realized. The elements of inner and outer orientation are known. The digital camera JVC TK-C1380E (physical resolution 752x548 pixels) is being used at present. The camera is mounted on the theodolite

Theo 010B (made by Zeiss). This theodolite is adapted for precise fixture of the digital camera (ŠTRONER, M., 2003).

The laser module forms a laser plane. The former laser Tesla TKG 205 (wave length 633nm) made a circle mark. That is why it had to be diffused by a cylindrical lens to the laser plane. Laser module DPGL-3005L-45 (power 5mW, wave length 532nm) which makes directly the laser plane is used at present.

The rotating platform has a constant rotation velocity (in accordance with required accuracy). It is necessary to level it to the horizontal plane and to determine the position of the center of rotation before measuring.

A 3D point is defined by intersection of the laser plane and an optic line. The laser plane crosses a measured object and creates a laser mark which is scanned by the digital camera. The optic line is determined from corrected image coordinates of the laser mark.

Each section (image) is independently transformed to the model coordinate system (rotating system). The issue is closely described in (KOSKA, B., 2004).

1.3 Software Solution of LORS

1.3.1 Self developed programs

The whole system consists of several programs which provide computing of all necessary configurations parameters, automatic scanning of image coordinates and finally computing of the 3D coordinates of the points on a scanned object.

The first group of programs provides computing of all configurations parameters (parameters of plane, coordinates of the rotating platform). A least square method is used for adjusting of these parameters. The issue is closely described in (KOSKA, B. - ŠTRONER, M. - POSPÍŠIL, J., 2004).

The second component is the program POWOK which provide treating images from the digital camera. It consists of a few modules. The module “Extrahovat XPV” provides extraction bitmap images from a video recording. It uses a special video card frame grabber X-Press plus, because of hardware coding of the video recording. The module “Základní vyhodnocení“ provides automatic scanning of the image coordinates of the pixels which correspond with a preset RGB filter (the coordinates of the laser mark). The module “Podrobné vyhodnocení” provides the automatic line evaluation of filtered out pixels in accordance with a selected criterion (the elimination of a multivalent laser mark, computing of the column width and the column average of the laser mark).

The last component is the program “SKENER”. This program computes 3D coordinates of points on a scanned object from configuration parameters of the system and from image coordinates of the laser mark.

1.3.2 Processing software 3Dipsos

The professional software for treatment of a point cloud 3Dipsos (made by Mensi) has been bought within the scope of the mentioned grant GA ČR Grant No. 103/02/0357. This software provides complete treatment of any point cloud and is also used for the 3D scanner CALLIDUS which is also hold by the Faculty of Civil Engineering.

1.4 Made and Planned Experiments

A few experiments which have confirmed the functionality of the whole system LORS have been already carried out. One of the scanned objects is shown as a model (Figure 2).

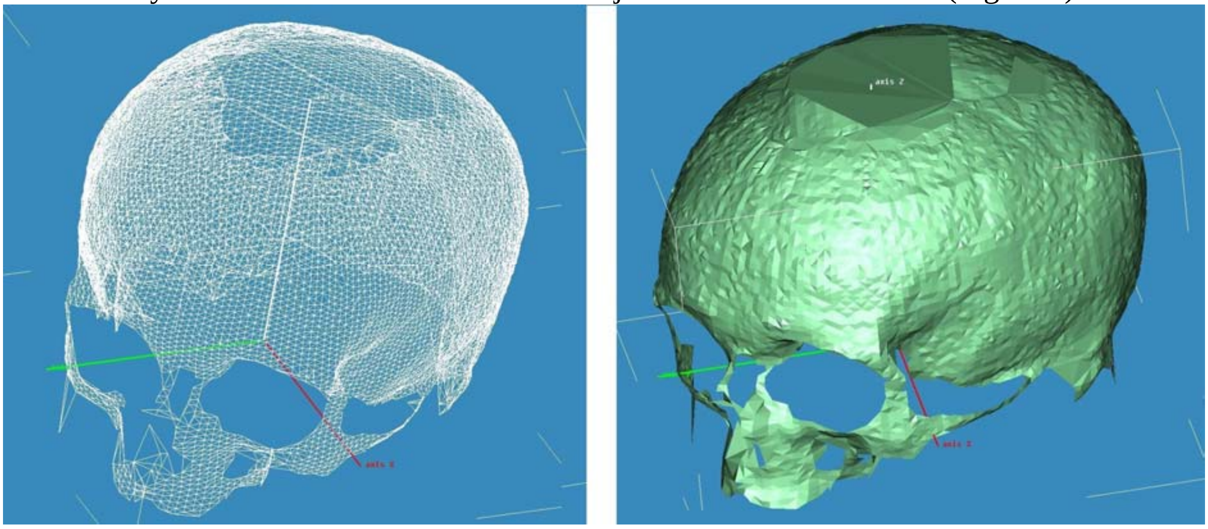

Figure 2: Model of skull measured by the system LORS

The special model for reliable determining of spatial accuracy of the system LORS has been created recently (Figure 3).

1.5 Future Development of the Dystem LORS

Another extension of possibilities of the system LORS is planned after determination of its spatial accuracy.

The first extension represents the more accurate digital camera Lumenera Lu120 (physical resolution 1280x1024/16 fps, progressive scan mode). This camera has been already bought. The others advantages of this camera are a direct connection by USB 2.0 port and recording without hardware video coding.

The second extension is color scanning. It can be realized only by a new program. There is no need of any additional hardware.

The scanning of larger objects is also planned after perfect mastering of all mentioned problems.

The latest information and results of the development of the system LORS will be present at the conference INGEO 2004.

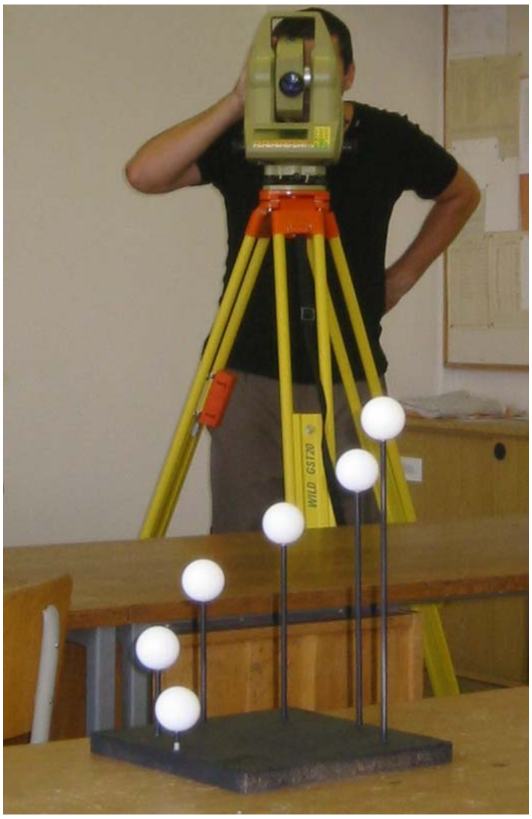

Figure 3: The special model for determining accuracy

1.6 Summary

The original system for 3D scanning of objects has been suggested and realized. The experiments already done have confirmed the functionality of the whole system LORS. It has validated the theoretical hypothesis of LORS creators.

The partial problems which helped creators to better understanding of whole problem of 3D scanning were solved during the development of the system LORS.

There is a plan of hardware and software development of the system LORS in the future.

2. TESTING OF LASER SCANNING SYSTEMS – EXAMINATION OF VARIOUS TYPES OF SURFACE UNDER VARIOUS ANGLES

This research is a follow-up to the previous one already published (KAŠPAR, M. - POSPÍŠIL, J. - ŠTRONER, M. - KŘEMEN, T., 2003).

Laser scanning is a relatively new progressive method of collecting spatial information. Initially, measuring with scanners might seem quick and simple. It is quite enough to examine a subject of interest from a few positions in order to scan from all the sides. However, later on, one finds that it is not that simple.

Prior to the measuring process itself, it is quite necessary to carefully check the subject and to focus, among other things, on the types of its surface available on the given subject since the quality of surface is one of the most important factors affecting scanning results.

A majority of laser scanners used in civil engineering for measuring distances within 100 meters use the polar spatial method for determination of the detail point position – a laser distance meter is used for length measuring. In order to measure the distance between a detail point and a laser distance meter (scanner), it is necessary to make sure that the laser distance meter -generated signal bounces back from the detail point and returns to the laser distance meter with an intensity sufficient for determining the distance. Whether the signal bounces back and its intensity depend, among other factors, on the reflection capabilities of the surface hit by the signal and the angle under which the signal hit the surface.

Reflection capabilities of the surface depend on qualities like its color, roughness, dispersion, wavelength used by the laser distance meter, etc.

Scanners must be able to handle different types of material reflection capabilities and different laser distance meter beam angles. That is why the goal of the following experiments was to find out how specific scanners handle that requirement.

For the purpose of the experiments, plates (150 x 300 mm) with various types of surface were produced (metals, wood, colors, glass, etc.).

The Cyrax 2500 scanner owned by the Stavební geologie a geotechnika company was used. The plates were positioned on a vertical wall and scanned from 5 positions from a distance of 25 m (Figure 4).

These positions were selected in order to make sure that the laser distance meter-generated beam hit the wall with the plates under approximately the following angles: 0gon, 30gon, 55gon, 75gon, 90gon. The density of scanning was 5 mm x 5 mm.

The Cyclone program was used for evaluation. Based on the obtained clouds of points, the program assigned particular colors to the individual points in accordance with the returned radiation intensity. The surface whose points were assigned the red color received its coefficient as b=1 (lowest intensity), the surface with the orange color received its coefficient as b=1.5, the surface with the yellow color received its coefficient as b=2, the surface with the green color received its coefficient as b=3, and the surface with the blue color received its coefficient as b=4 (highest intensity).

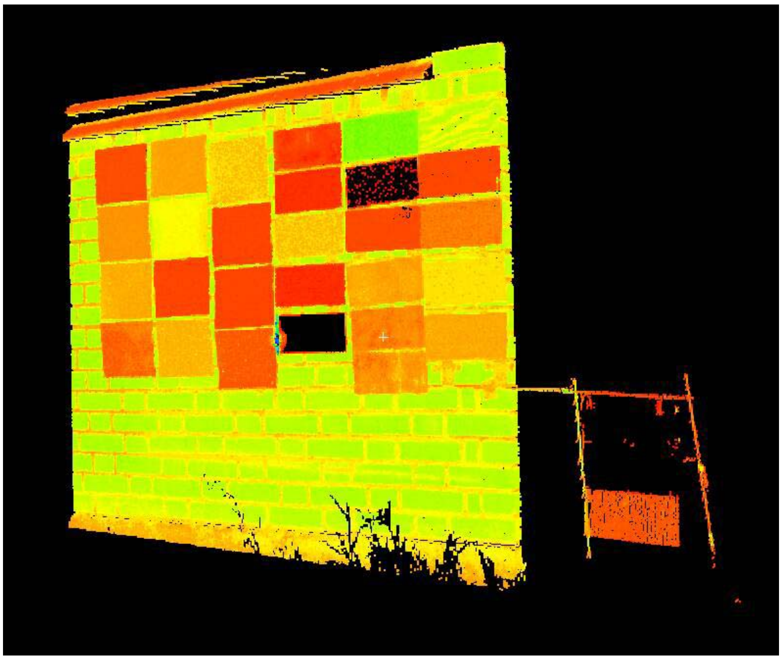

Figure 4: Plates with various types of surface – cloud of points

After this, a theoretical amount of points that should have been hit by the beam and scanned was determined for each of the plates. Following that, the actual amount of scanned points was identified. The percentage *k* of actually scanned points of theoretically possible ones was determined from those two types of data. Another computation produced the material suitability *p* which is a product of the *b* and *k* values. The results are available in Table 1. It is possible to conclude that materials and configurations whose *p* value is lower than 100 % are not suitable for scanning in the given combination.

Scanning angle		Position 1 (α_1= 0^g)			Position 2 (α_2= 30^g)			Position 3 (α_3= 55^g)			Position 4 (α_4= 75^g)			Position 5 (α_5= 90^g)		
No.	Material	k[%]	b	p[%]	k[%]	b	p[%]	k[%]	b	p[%]	k[%]	b	p[%]	k[%]	b	p[%]
1	Clear glass	100	2	200	0		0	0		0	0		0	0		0
2	Smoke glass	100	1	100	0		0	0		0	0		0	0		0
3	Milk glass	100	2	200	100	1.5	150	100	1.5	150	100	1.5	150	100	1.5	150
4	Natural wood	100	3	300	100	2.5	250	100	3	300	100	2	200	100	2	200
5	Wood - orange	100	3	300	100	1	100	100	1	100	100	1	100	100	1	100
6	Wood - brown	100	3	300	100	1.5	150	100	1.5	150	100	1	100	100	1	100
7	Wood - blue	100	3	300	100	2	200	100	2	200	100	1.5	150	100	1.5	150
8	Wood - grey	100	2	200	100	1.5	150	98	2	196	100	1.5	150	100	1.5	150
9	Sheet metal – yellow	100	3	300	100	3	300	100	3	300	100	2	200	86	1.5	129
10	Sheet metal - black	100	1.5	150	13	1	13	2	1	200	0		0	0		0
11	Sheet metal – primary paint	100	1	100	100	1.5	150	100	1.5	150	100	1	100	100	1	100
12	Metal sheet - corroded	100	1.5	150	100	1.5	150	100	2	200	100	1.5	150	100	1.5	150
13	Metal sheet	100	4	400	100	1.5	150	100	1	100	100	1	100	64	1	64
14	Zinc-coated	100	4	400	100	1.5	150	100	1.5	150	100	1	100	97	1	97
15	Cuprum	100	3	300	100	1	100	73	1	73	12	1	12	10	1	10
16	Sheet metal - blue	100	1.5	150	100	1	100	100	1	100	25	1	25	0		0
17	Sheet metal - green	100	3	300	100	2	200	100	2	200	100	1.5	150	100	1	100
18	Sheet metal - red	100	2.5	250	100	1	100	100	1	100	19	1	19	0		0
19	Mirror	100	1.5	150	6	1	6	0		0	0		0	0		0

Table 1

It is clear from the table that the Cyrax 2500 system is not suitable for the scanning of clear glass (materials No. 1 and 2), black shiny color (material No. 10), and the mirror surface (material No. 19).

The second measuring was conducted via the Riegl Z360 scanner owned by the Geodis Brno Company. The plates were again scanned from a distance of 25 m. This time, the scanner's position remained the same during the whole measuring process. The different hit angles (0gon, 30gon, 55gon, 75gon, 90gon) of the laser distance meter-generated beam were produced by the turning of individual scanned plates under precise angles. The density of scanning was 5 mm x 5 mm.

The RiSCAN PRO program produced by the RIEGL Company and the MDL application TerraScan for the MicroStation program were used for evaluation. That scanner enables the direct measuring of the returned radiation intensity, therefore, it is possible to directly assign the intensity of returned radiation to individual colors (Figure 5).

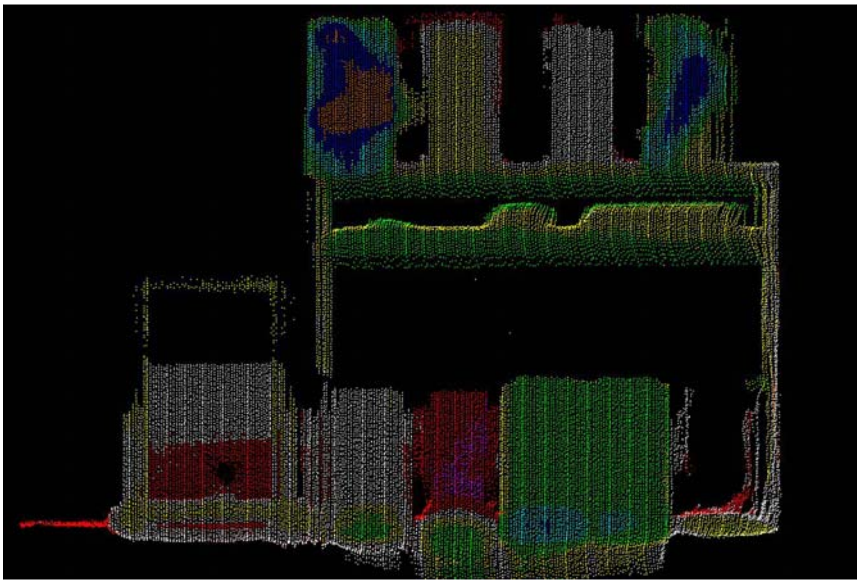

Figure 5: A few plates with various types of surface – cloud of points

Specifically, the purple color was used for 10-20 %, the red color for 20-30 %, the white color for 30-40 %, the yellow color for 40-50 %, the green color for 60-60 %, the light blue color for 60-70 %, the dark blue color for 70-80 %, and the brown color for 80-90 %.

The evaluation showed that the selected method of plate measuring was not the best one, therefore, it was not possible to simply produce a similar table as with during the measuring of the Cyrax 2500 scanner. Despite that small handicap, the evaluation showed that the Riegl Z360 scanner was able to scan a majority of materials without problems, however, it faces troubles during the scanning of clear and smoke glass, mirror, and shiny black color – similar to the Cyrax 2500 scanner. Another phenomenon that was detected during the measuring with the Riegl Z360 scanner was the quite clear spread or noise of points.

It is clear from both of the conducted experiments, that the scanning of transparent and shiny materials causes substantial difficulties. That is why we recommend avoiding the scanning of those materials or at least being aware of potential complications associated with their scanning. Due to the very interesting results, the experiments will continue with the CALLIDUS and Mensi GS200 scanners.

This research has been supported by GA ČR Grant No. 103/02/0357.

REFERENCES

Štroner, M., 2003**:** *Návrh a kalibrace měřicího systému tvořeného teodolitem a digitální kamerou* (Design and Calibration of a Measuring System Composed of the Theodolite and the Digital Camera). Stavební obzor, No. 2, pp. 56-60, (Czech).

Koska, B., 2004: *Laserový a optický rotační skener* (Laser and Optic Rotating Scanner). In: JUNIORSTAV 2004 [CD-ROM], Brno, (Czech).

Koska, B. - Štroner, M. - Pospíšil, J., 2004**:** *Algoritmus určování rovnice obecné roviny pro laserové skenování včetně rozborů přesnosti* (An Algorithm of Determination of the General Plane Equation for Laser Scanning, Including Accuracy Analyses). Stavební obzor, No. 2, pp. 55-60, (Czech).

Kašpar, M. - Pospíšil, J. - Štroner, M. - Křemen, T., 2003**:** *Practical Testing of the Cyrax 3D Laser Scanning System.* Slovak Journal of Civil Engineering, Vol. 11, No. 1, pp. 26-31.

CONTACTS

M.Sc. Bronislav KOSKA, M.Sc. Tomáš KŘEMEN, Martin ŠTRONER, Ph.D., Assoc. Prof. Jiří POSPÍŠIL, Assoc. Prof. Milan KAŠPAR
Department of Special Geodesy, Faculty of Civil Engineering, Czech Technical University in Prague
Thákurova 7
166 29 Prague 6
THE CZECH REPUBLIC
Tel. + 420 233 337 489
Email: pospisil@fsv.cvut.cz
Web site: wwwold.fsv.cvut.cz/depts/k154a.htm