NEW METHODOLOGIES FOR ARCHITECTURAL PHOTOGRAMMETRIC SURVEY

P. Boccardo, G. Comoglio
Dipartimento di Georisorse e Territorio
Politecnico di Torino
C.so Duca degli Abruzzi, 24
10129 Torino – Italy
e-mail: BOCCARDO@POLITO.IT,COMOGLIO@POLITO.IT

KEY WORD: Laser-scanner, architectural photogrammetry

PURPOSE:

In recent years new survey technology have been implemented in order to execute more accurate and effective measurements. In particular, the investigation of architectural goods have imposed to take into account the reconstruction of 3D models for more effective faÁ ade analysis and 3D navigation. For this purpose it is necessary to derive an object digital elevation model (DEM) useful both for volume assembly and for digital orthoprojection methods. Traditionally, a DEM surveying is performed by means of profiling topographic total stations, or derived by photogrammetric stereoplotting. The aim of this paper is the first analysis of an automatic DEM surveying device capable to acquire thousands of points in few seconds with high precision and accuracy. Following the CIPA test conducted on Vienna Karlsplatz underground station designed by an art noveau master, Otto Wagner, a complete test field has been conducted. This paper presents the first result of the above mentioned device, an optical-electronic laser scanner.

1. INTRODUCTION

1.1 Laser-scanner state-of-the-art

In recent years a new technology has been implemented in order to reconstruct 3D models; this technology, based on optical-electronic devices, uses an high intensity pulse directed toward the object to survey in order to have a distance from the device itself. From thousand of different pulses a digital image is derived where all the measurements performable on single points are pure 3D locations.

Laser-scanners have been successfully mounted onboard of satellite and aerial platform first as telemetric devices capable to define, in an indirect way, the spatial position of the platforms themselves; recently, aerial laser-scanner have been mounted onboard of airplane in order to derive high precision DEM, being the precision independent from sensor and target distance. Unfortunately, control points definition, useful for DEM-to-photogrammetric image warping, is particularly difficult to determine because of the instability of laser-scanner rotating mirror and of the low accuracy in determining projection center parameters without kinematic GPS.

No metric tests have been conducted on static laser-scanner before, where warping and photogrammetric taking parameters could be derived in an easiest way. In § 2 this approach will be deeply described.

1.2 Laser-scanner operating principles

The laser-scanner used, named LMS-Z210 is manufactured by RIEGL-Laser Measurement System located in Horn Austria.

LMS-Z210 laser-scanner (shown in fig. 1) is a fully portable sensor, specifically designed for the acquisition of 3D images. A rotating mirror directs the internal laser rengefinder's transmit beam over a precise angular pattern. The resulting range measurements comprise a very accurate 3D dimensional representation of the acquired scene. LMS-Z210 device operates by any standard PC or notebook, measuring range up to 350 m, with a field of view up to 80°X340°. The scan time is

Figure 1 – LMS-Z210 laser-scanner

approx. 30 to 240 s, with a nominal metric accuracy of ± 2.5 cm.

Until now, the laser sensor has been used for 3D imaging of building and structures, topographic mapping of quarries, mines and tunnels, scene acquisition for virtual reality modeling application and for dimensional measurements of vessel, furnaces and tanks.

The principles of operation are shown in fig. 2.

The range finder electronics (1) is based upon a classical laser distance meter, optimized in order to meet the requirements of high speed scanning (fast laser repetition rate, fast signal processing and high speed data interface.
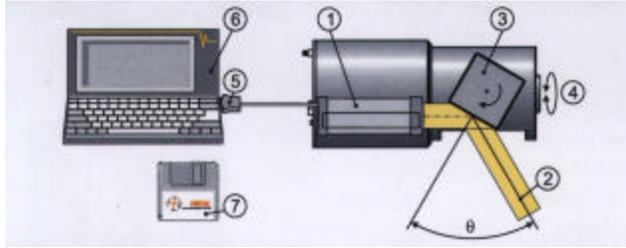

Figure 2 – Laser-scanner operating principles

The fast angular deflection ("line scan") of the laser beam (2) is realized by a rotating polygon (3) with a number of reflective surfaces. It rotates continuously at adjustable speed to provide an undirectional scan within an angle of 80°. The slow scan ("frame scan") is provided by rotating the complete optical head (4) up to 340°.
The gained information of range, signal amplitude and angle is provided by an 8 bit parallel data output which can be connected directly to the ECP compatible LPT printer port (5) of a PC (6). This PC has to be equipped with specific software (7) running under WIN95 or WINNT for data acquisition, real time display and post-processing. The displayed 3D range images can be zoomed and copied to the clipboard, while for further processing, the scanner data are logged to disk.
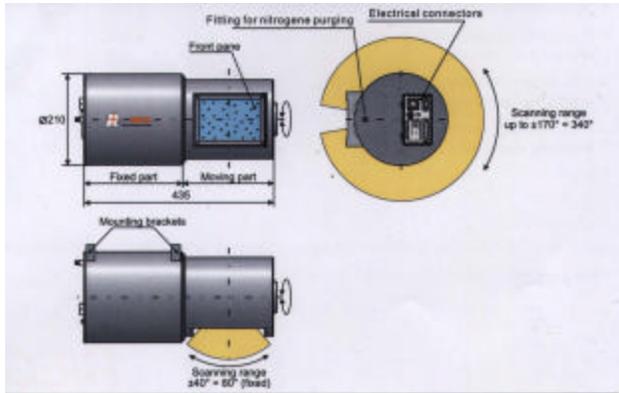In figure 3 the dimensional drawings are shown.

Figure 3 – Laser-scanner dimensional drawings

In figure 4 the inner instrument reference system is shown.

The data provided by LMS-Z210 include range, bearing angle, inclination angle and intensity information for each laser measurement. Measurement data are organized in the data file sequentially, line by line starting in the upper left corner of the image. Each measurement is represented by 8 bytes, 2 byte range, 2 byte bearing angle, 2 byte inclination angle and 2 byte intensity including housekeeping data. The precision units used are 8 mm for range, 0.01 gon for the angles, and 1 for the intensity data. The 3D image data are complemented by an header which states the number of bytes of the raw data (4 bytes integer), the number of lines of 3D data (2 bytes), and the number of measurements per line (2 bytes).
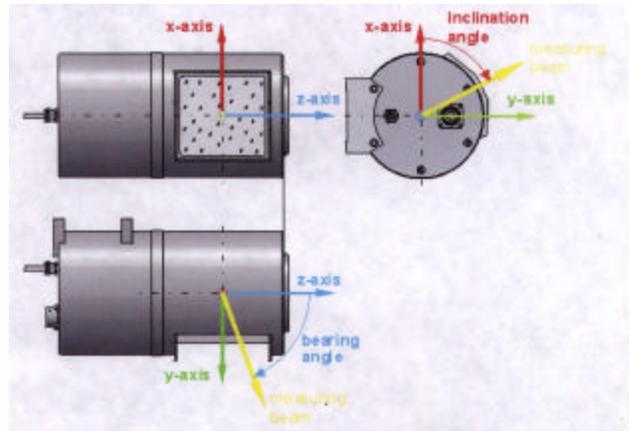

Figure 4 - Inner instrument reference system

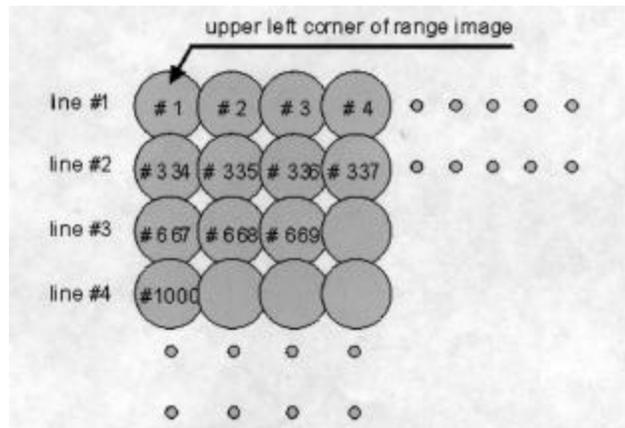In figure 5 an example of the image data is shown.

Figure 5 – Range image

In the following tables, technical data for LMS-Z210 laser-scanner are shown.

Rangefinder performance	
Measurement range	350 m, reflectivity >=80%
Minimum range	2 m
Measurement accuracy	±2.5 cm, <=20 ppm
Measurement resolution	2.5 cm
Measurement rate	20000 Hz
Laser wavelength	0.9 m
Beam divergence	approx. 3 mrad
Eye safety	Class 1

Table 1 – Rangefinder performances

Physical data	
Main dimension (L X diam.)	435X210 mm
Weight	Approx. 13 kg
Interface	Parallel, ECP
Power supply	11-18 V DC, max. 3 A

Table 2 – Physical data

Scanner performance	
Line scan	
Scanning range	± 40° (80° total)
Scanning mechanism	Rotating polygonal mirror
Scanning rate	20 scans/s
Angle stepwidth	0.24°
Angle readout accuracy	0.036°
Frame scan	
Scanning range	± 150° (300° total)
Scanning mechanism	Motor driven optical head
Scanning rate	5°/s
Angle stepwidth	0.24°
Angle readout accuracy	0.018°

Table 3 – Scanner performances

Temperature range	
Operation	-10 °C - +50 °C
Storage	-20 °C - +60 °C

Table 4 – Temperature range

1.3 Acquisition and post-processing software

The software included with the laser-scanner instrument allows both the assistance in the acquisition phase and image post-processing. The starting shell (fig. 6) is the same for the two modes.
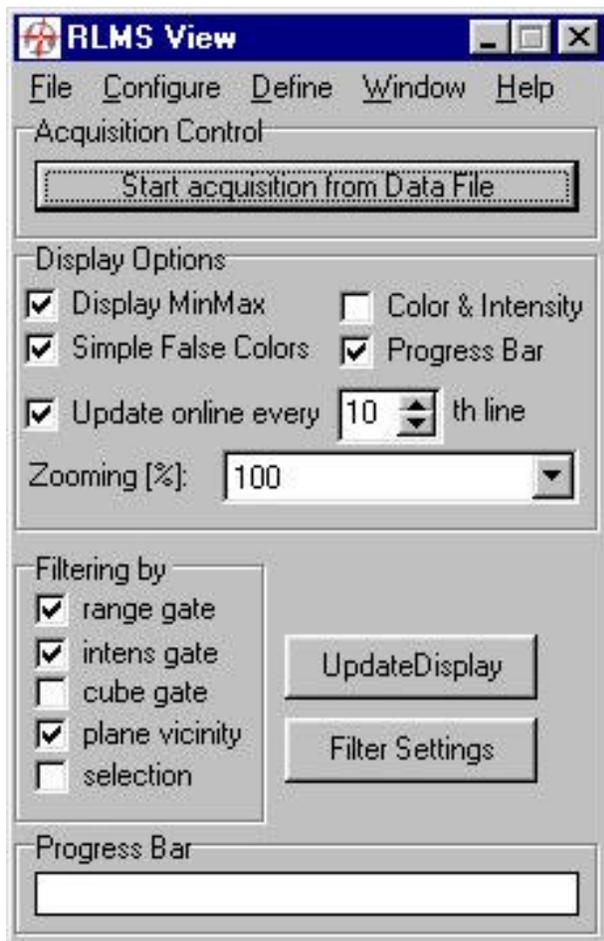

Figure 5 – The software starting interface

It is possible to control line and frame scan dimensions, viewing the acquiring image in real-time, filtering it both from radiometric and distance point of view, and obviously zooming and pan functions are always available.

Every acquisition is composed by two different images: the range one (fig. 6) measures the distance of every single point from the instrument (where the 2 bytes field corresponds to the distance measured in cm) while the intensity image (fig. 7) measure the reflectivity of the target in the near-infrared spectral band (0.9 m wavelength)
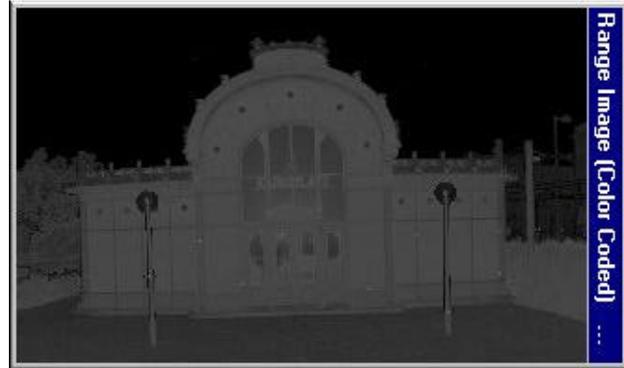

Figure 6 – Range image

Figure 7 – Intensity image

An ancillary window (fig. 8) shows some image important parameters such as image size (lines and rows), frame
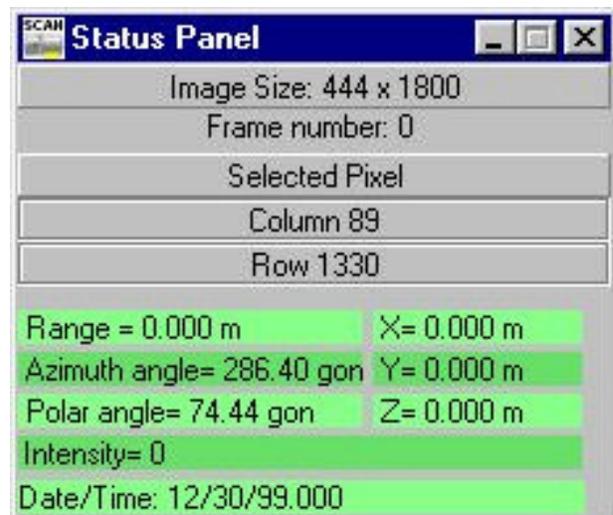

Figure 8 – Staus panel

number, selected pixel (and its image position) and geometric and radiometric characteristics of the above pixel (range, azimuth and polar angle, intensity). It is also possible to reference the inner system of the original image, associating to single cells, 3D previously surveyed coordinates; the software will perform a plane transformation in order to rectify the image.

2. TEST FIELD

2.1 Otto Wagner's Karlsplatz underground station

In 1990 a small test object had been selected, photographed, measured and documented, in order to get a well-checked materials to train students and photogrammetrists as well as to evaluate internationally the results of the analytic photogrammetric amount of control information. The test object was Otto Wagner's Stadtbahn Station buildings on the Karlsplatz in Vienna (fig. 9), a masterpiece of Art Nouveau, built in 1898-1899.

Figure 9 – Otto Wagner's underground station in Karlsplatz, Vienna

2.2 Performed surveys and measurements

This test field planned different acquisitions in order to reconstruct a 3D model of the underground station, leaving to future analysis a metric test of the image acquired by the laser-scanner LMS-Z210.

In fig. 10 is shown a sketch of the different taking positions useful for 3D reconstruction.

Figure 10 – Scanner taking positions

In the following figures are shown all the different 5 takings; the images are range measurements where pixels varying from orange to green represent closer to far points.
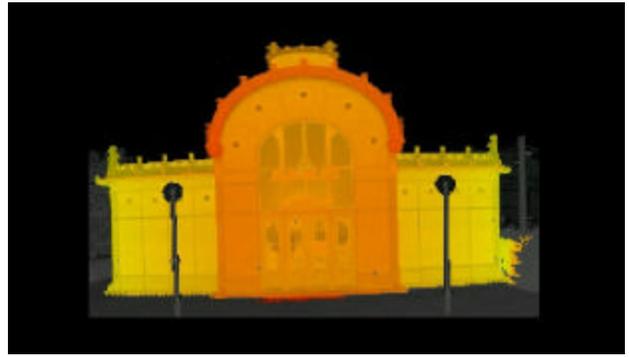

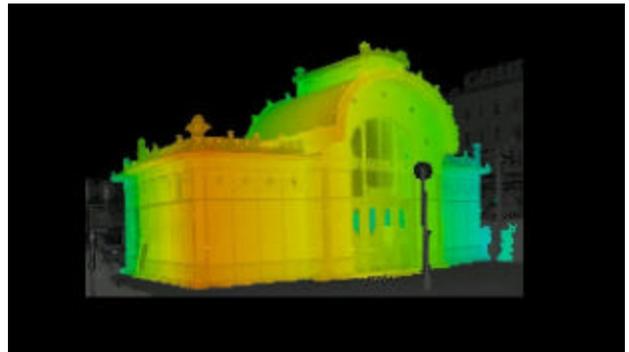Figure 11 – First taking position

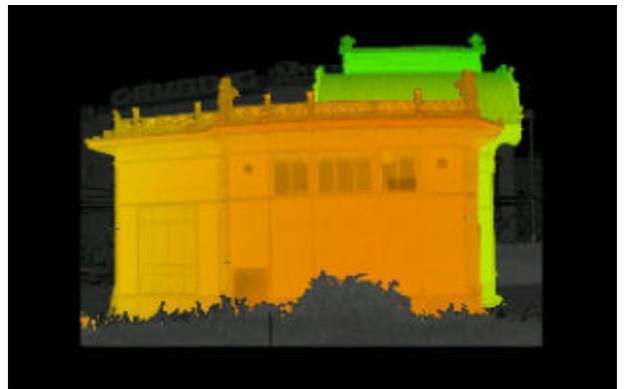Figure 12 – Second taking position
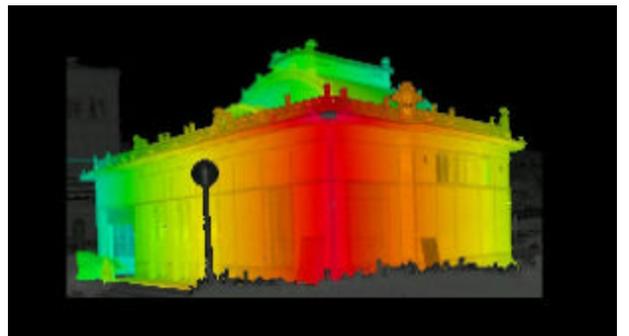

Figure 13 – Third taking position
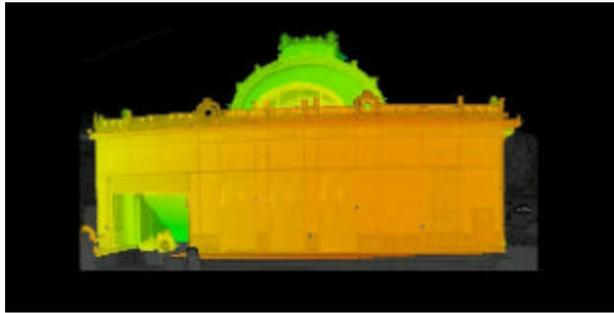

Figure 14 – Fourth taking position

Figure 15 – Fifth taking position

Acquisition time has been varied from few seconds to couple of minutes; for all the acquisitions, taking also into account the instrument moving, less than one hour was necessary.

3. POST-PROCESSING

The post-processing phase include the 3D reconstruction by means of tie points, materialized onto the underground station using reflective stickers (fig. 16).

Figure 16 – Reflective sticker

The software, by means of an autocorrelation procedure is capable to locate the 3D position of the reflective stickers (characterized by a high reflectivity in the near-infrared wavelength), imposing the correspondence of the coordinates (in a given reference system) of them in the different images (tie points).

The 3D reconstruction generates 3D files (in a 3DD file format) that can be easily viewed using free-of-charge internet downloadable software such as COSMOS (fig. 17).

In figures 18 and 19 different 3D views are shown.

4. RESULTS ACHIEVED

The 3D model reconstruction can be easily performed thanks to the capability of the LMS-Z210 laser-scanner and the good potentialities of the post-processing software. No problems raised during the surveys neither in the image processing phase. The capability of the acquiring system to overpass glass surfaces (with high transmittance coefficient and refraction index) could be annoying for architectural surveying, particularly for object

distance misplacement (all the features behind glass surfaces) and shift caused by the refraction coefficient.
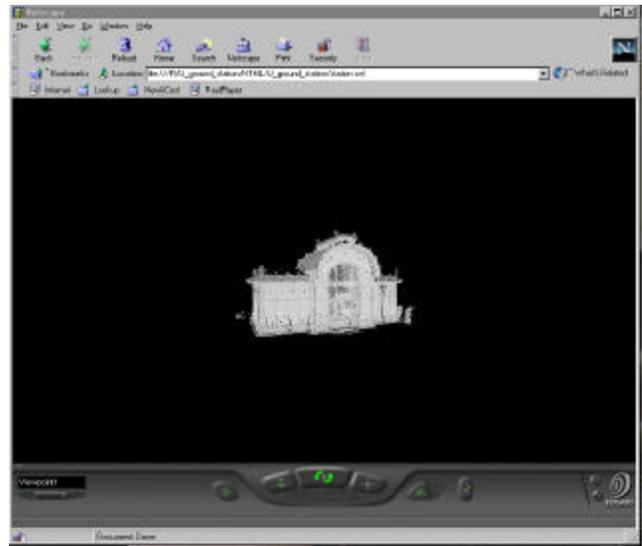

Figure 17 – Cosmos 3D viewer

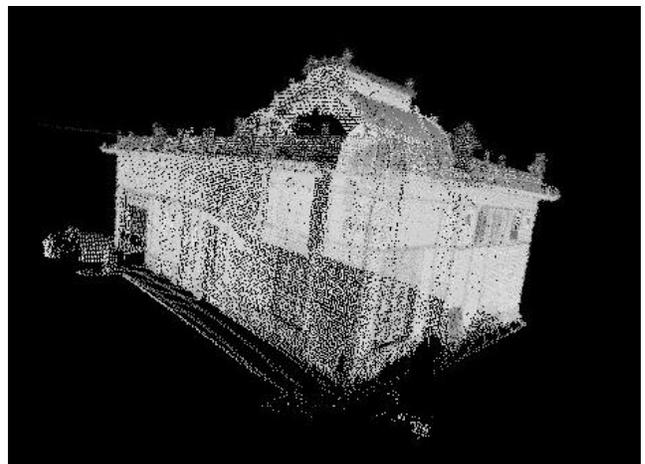Figure 18 – 3D image reconstruction

Figure 19 – 3D image reconstruction

4. CONCLUSIONS AND FURTHER DEVELOPMENT

According to the authors the impressive capabilities of laser-scanner instruments (in terms of effectiveness, user friendliness and surveying time) can be the solution of a broad range of different problems in architectural photogrammetry, but also when other target has to be surveyed (for example in the evaluation of quarries volumes, civil infrastructures, and so on).

In addition, the cost of the laser-scanner (approx. 100.000 DM), seems to be convenient for the huge application surveying spectrum; professional use (in particular if compared to standard total station price) could be mortgaged in few years of activity.

Future studies should evaluate the metric accuracy of the system, in order to include this instrument class in future surveying specifications.

5. ACKNOWLEDGMENT

5. REFERENCES

P. Waldhaeusl, A test object for architectural photogrammetry: Otto Wagner's Underground station Karlsplatz in Vienna, in XIV CIPA International Symposium, 2-5 October 1991, Delphi, Greece, pagg. 247-251

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