

# FIRST EXPERIENCES WITH THE TRIMBLE GX SCANNER

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### ABSTRACT:

Trimble introduced a new generation of terrestrial laserscanners (TLS) in October 2005. It was on the one side a further development of the Mensi GS200 series and on the other hand presented as “the 3D scanner that thinks like a surveyor”. The Trimble GX was tested regarding its precision, accuracy, attitude of reflection at different coloured surfaces and materials. A specific test field was used for the tasks.

Furthermore the authors report about first projects in the fields of architectural and topographical applications, as for example the Documentation of the „Pontonniers International High School“ in Strasbourg, were the levelling of the laserscanner and the direct georeferencing of the point clouds with the new workflow has been tested.

Specifically very interesting was the testing of the traditional total station workflow which is up to now uncommon for TLS systems: the scanner can be set up over known points measured with flat targets to provide a direct relationship to existing ground control. The workflow available for the Trimble GX laserscanner is close to the standard fieldwork methods where a network of control points measured by GPS or total stations are now also used as reference stations for the laserscanner.

Measurements between stations commonly referred to as traverse measurements, provide an instant relationship between multiple stations and allow the user to view homogenous data in the field without additional post processing. The quality and extent of the survey data can thus be verified in the field. A comparison of standard field methods and geodetic adjustments to the corresponding 3D scanner survey workflow are presented, based on experiences with both Pointscape and Pocketscape software.

## 1. INTRODUCTION

Both groups had at the same time the chance to get this new equipment for their institutions and used this opportunity independently for intensive tests and a following joint comparison of their experiences.

The Trimble GX terrestrial laserscanner was the follow-up model of the former Mensi GS200 series TLS. It uses a Class 2 pulsed 532 nm, green laser with a standard range of 200m and an “overscan” mode up to 350m. The field of view is limited by 360° x 60°, with an asymmetrical vertical part of about 40° above the horizon. The scanning speed is up to 5000 points per second.

The scanner uses an auto focus method for the laser which showed to be very useful mainly for close range applications. This feature guarantees a constant small laser spot even at different distances within a scan. The size varies from 0.3 mm at 5 m up to 1.5 mm at a distance of 25 m. This makes sense in combination with a spatial resolution as high as up to 3.2 mm at 100 m.

The built in video camera is used for both, framing of the area of interest as well as colouring the point cloud.



Figure 1. Trimble GX laser scanner

## 2. TESTING OF THE SCANNER

### 2.1 Test with RAL international colour coded system

First measurements with the TRIMBLE GX Scanner in the laboratory of the Surveying and Geoinformation Unit at the University of Innsbruck showed a specific measurement – behaviour, dependent on the colour of the surface. Additionally the resulting point cloud had some unexpected properties.

To further investigate these effects we established a test field. This 12 x 16 matrix scheme consists of 192 different RAL colours, where each colour is represented by a rectangle of 35 mm x 60 mm (see fig.2). So a wide range of colour, reflectance and brightness is guaranteed. RAL ([www.ral.de](http://www.ral.de)) is a colour space system developed in 1927 by the German Commission for Delivery Terms and Quality Assurance. That colour system is mainly used to describe Paint colours.



Fig. 2. RAL test field with international colour coded system

The test chart has been measured with high resolution, fixed focus and 4 shots per point at a distance of about 4 m.

Each coloured rectangle was evaluated individually yielding a mean plane and associated measurement noise, resulting from about 900 points per area.

A remarkable correlation is outlined between a relative shift of the adjusted planes, the measurement noise and the intensity of the reflected signal.

The following figure 3 presents exemplarily the results of the third coloured row of the test field. The lowest curve describes the bias of the individual colour fields against a reference plane which was defined by white areas only.

The difference between minimum and maximum level is up to 5 mm. The furthest levels seen from the scanner are the basis colours orange (Y30) and blue (B40) at the left side and purple-violet (RAL 4007) and ultra-marine-blue (RAL 5002) at the right end of this line.

The levels of all other colours – from sand-yellow (RAL 1002) on the left to the right sky-blue (RAL 5015) – do not differ significantly.

The middle curve shows the noise of the point measurements. The values describe the RMS error of the approximately 900 measuring points in relation to their individual rectangular plane. The significant correlation between the bias of the levels and the noise is remarkable.

The top curve shows the intensity of the reflected signal. The bias of the individual colour planes and the intensity values are obviously correlated. The computed correlation coefficient has a significant value of  $r = -0.81$ .

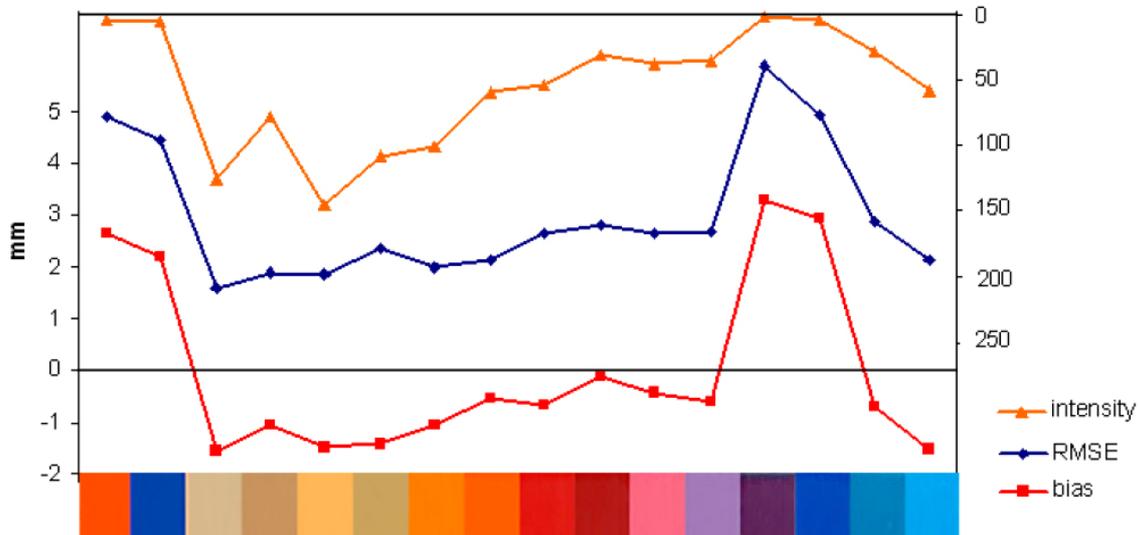


Fig. 3. Correlation of intensity, bias and noise

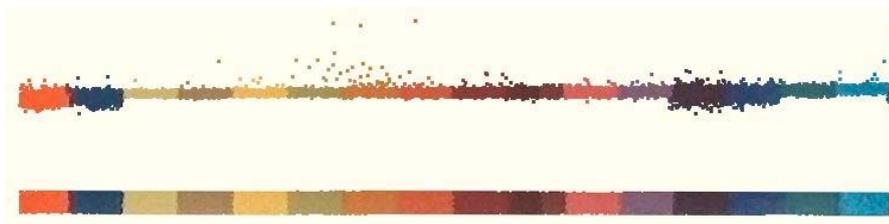


Fig. 4. Frontal view and side view of line 3 of the test field showing the differing noise

Generally a correlation between the bias of the planes - also for all other lines of the test field - and the intensity values of the signal is visible. Weak intensity of the signal is coupled with bias of the level and a large noise.

The different biases of the colour planes in measuring direction can be interpreted as a changing additive constant.

The magnitude of this phenomenon surely does not concern many applications. But regarding possible applications with higher requirements for accuracy – particularly in engineering surveying – we made an attempt to find out more about the additive constant.

## 2.2 Laboratory network adjustment

### 2.2.1 Test 1 (Innsbruck)

In the laboratory of the Surveying and Geoinformation Unit a small-scale, precise calibration baseline is available, consisting of 9 concrete pillars with forced centring device (Fig.5).

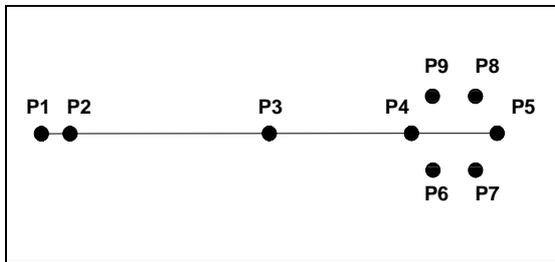


Fig. 5. Configuration of the base line

Between the columns P1, P2, P3, P4 and P5 the distances in all combinations were measured from the scanner to the target spheres (Fig.6a). These are made of matt white plastic material, with a diameter of 76.2 mm and centred by an adapter. The measurement is done indirectly via the scanning of the spheres with high point density and reduction to the centre. The accuracy of the resulting distance is thus about 1 mm.



Fig. 6a: Target spheres with forced centring device

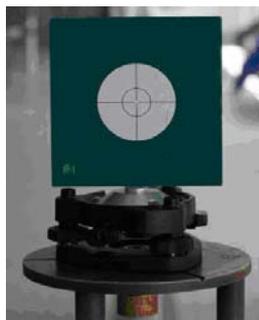


Fig. 6b: Trimble target in a tribrach

The network adjustment of the base line measurements delivers the additive constant as 7.8 mm with the associated standard deviation of 0.5 mm. The additive constant therefore is highly significant and should be considered to be corrected for precise applications. In this test, the additive constant is negative, i.e. measured distances are too long, and 7.8mm have to be subtracted.

### 2.2.2 Test 2 (Strasbourg)

Another test made of all possible measurements between 4 aligned pillars ((in the range of 7m to 31m in this test) equipped with Trimble targets (Fig. 6b) delivers also an additive constant of 8mm. But in this test, the additive constant is positive, i.e. measured distances are too short, and 8mm have to be added to the distances displayed by the GX scanner.

In table 1, we compare data from geodetic measurements and corresponding distances from the GX scanner (based on measurements of Trimble targets).

Stations	Points	Horiz. Dist. Tachéo. TC2002 (meters)	Horiz. Dist. (Laser GX) (meters)	Diff. (mm)
P4	I03	14,754	14,744	+10
	P18	23,121	23,107	+14
	P9	17,963	17,950	+13
	A1	20,042	20,029	+13
	B1	13,187	13,177	+10
P9	C1	4,517	4,503	+14
	P4	17,963	17,950	+13
	C1	16,499	16,489	+10
	I03	15,368	15,359	+9
	A1	5,776	5,774	+2
I03	P18	10,120	10,113	+7
	A1	12,548	12,541	+7
	P9	15,368	15,360	+8
	B1	7,312	7,311	+1
	C1	10,321	10,308	+13
P18	P4	14,755	14,745	+10
	I03	12,779	12,770	+9
	A1	4,389	4,382	+7
	P9	10,119	10,113	+6
	B1	9,936	9,927	+9
	P4	23,121	23,113	+8

Table 1. Comparison of distances measured by TC2002 Total Station and GX scanner on Trimble targets.

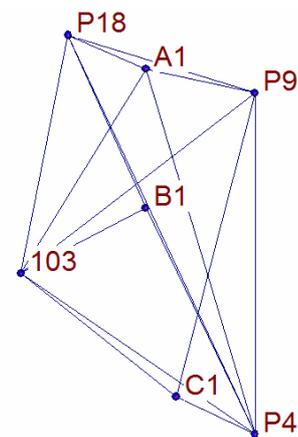


Fig. 7. Test Network corresponding to data of Table 1

In a first stage, a reference dataset from the angles and distances measured with the TC2002 total station has been adjusted with a total error factor of 0.7mm (StarNet software).

Considering the 7 points of the network as fixed, we got in a first adjustment a total error factor of 9.6mm from the GX scanner distances and thus confirmed the systematic error on the distances (8mm). After corrections of the distances, the total error factor drops off to 3.1mm.

### 3. LASER SCANNING WORKFLOW

The traditional scanning methodology is based on measurements of common targets or spheres to relate multiple scans together or to relate measurements to an existing control network. At least three common targets are required between two point clouds in order to merge them.

The new workflow proposed with the GX scanner is close to the traditional total station survey workflow (Lemmon & Biddiscombe, 2006):

- the instrument can be accurately set up on a known ground point
- the instrument can be accurately levelled using an electronic level (Fig. 8)
- the height of the instrument is measured over a known ground point
- the height of the backside target is measured over a known ground point
- the observations towards the backside targets orientate the survey

The scanner is thus set up over known points and provides a direct relationship to existing ground points. Measurements between stations commonly referred to as traverse measurements, provide an instant relationship between multiple stations and allow the user to view homogenous data in the field without additional post processing. The quality and extent of the survey data can thus be verified in the field, reducing survey time or further re-measurements.

The GX scanner provides a dual-axis compensator for levelling the instrument over a known point. The dual-axis compensator actively corrects the horizontal and vertical angles during the scanning.

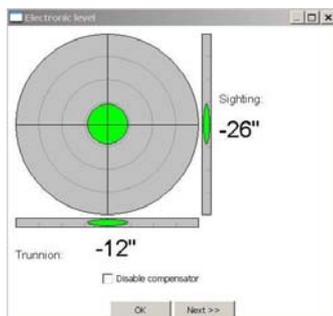


Fig. 8. Electronic level available in the GX scanner

The levelling of the laserscanner and the direct georeferencing of the point cloud is of great interest for outdoor projects (see the example in §4).

The scanner is supported by Trimble's PointScape data acquisition software for use on regular notebook computers. Trimble also offers PocketScape, a handy software solution, which allows users to control the GX with a Pocket PC. PocketScape is Recon friendly. Transfer data to notebook for immediate verification and editing while other Pocket PC controls the scanner, or during transfer of scanner to next station. Easy-to-use graphic interface: View z-pictures and auto-panorama in full window mode with pan, enhanced display visualization (points, Z-picture 3D emulation). In terms of scanning options, it is possible to have real-time true coloring, automatic associate panorama image with corresponding scan. One tool which can easily be indispensable is the automatic reflective flat target detection, enhanced target/sphere scanning geo-referencing capability

(acquired point and/or import survey file). It is also possible to use a framing: scan-time estimations and execute scan based on available time limit.

### 4. APPLICATION BASED ON SCANNING SURVEY WORKFLOW: DOCUMENTATION OF THE „PONTONNIERS INTERNATIONAL HIGH SCHOOL“ IN STRASBOURG

We report in this section about a first experience with the GX scanner in the field of architectural documentation. In the frame of an order of the Alsace Region, the group of INSA Strasbourg has been in charge some months ago of the 3D modelling of the Pontonniers high school in Strasbourg (a site with typical buildings from the 18<sup>th</sup> century). The study aimed to document 7 buildings (fig. 9) to proceed to a complete diagnosis in order to conform to the current regulation as well as to insure the future of the patrimony and among other the general maintenance of roofs and facades.

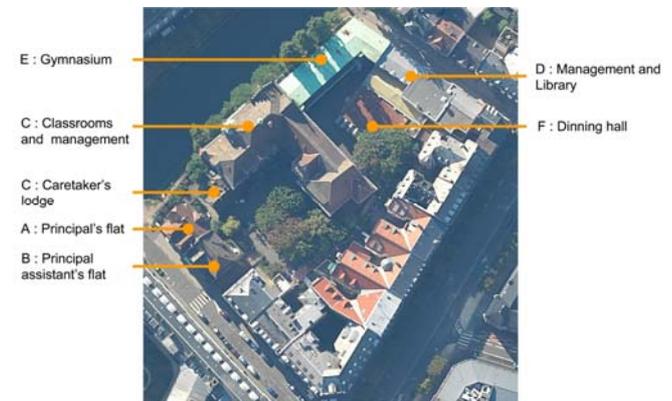


Fig. 9. Aerial view of “Pontonniers International High School” area in Strasbourg

As the scanner has only been purchased at the end of the project, we used Canon EOS 5D and Rollei D7 Metric digital cameras and photogrammetric techniques for the modelling process.

This project was a good opportunity to test the new workflow proposed with the GX scanner. A network of known points was available and the scanner has been set up as described in §3. The objective was to measure georeferenced point clouds and avoid any other registration process in Realworks. Each part of the site has been scanned twice from at least two different stations.



Fig. 10. Trimble GX scanner during the survey

The scanner stations have been defined by taking into account problems due to the vegetation, traffic, narrow roads, height of surrounding buildings, hours of sunshine, visibility of reference points. An overview of the different stations (more than 20) is shown in fig.11.

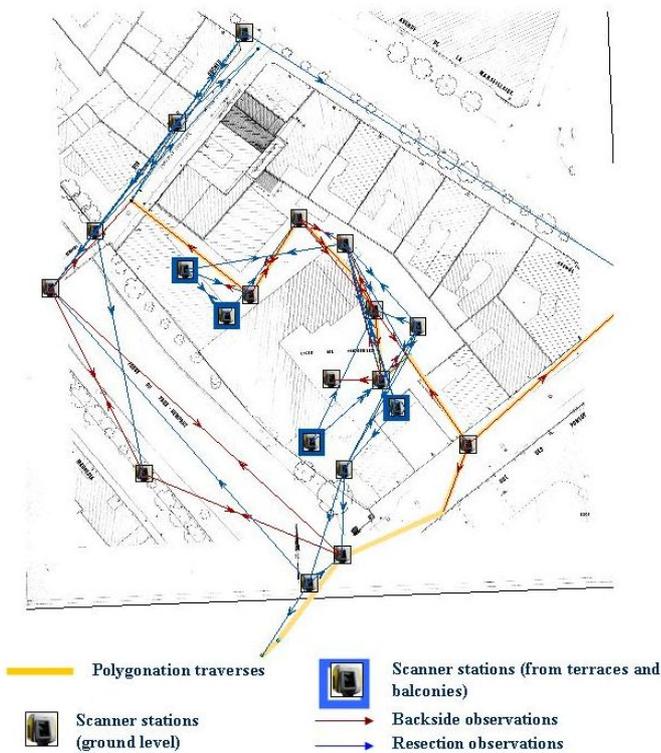


Fig. 11. Scanner stations and measured traverses in the Pontonniers Project (Strasbourg)

Station coordinates can be computed by resection techniques, when no known point is available (free stationing). Residuals in X, Y and Z are displayed in the station setup window (fig. 12). In this project, the range of the residuals for both kind of scanner stations (known point or resection) has been about 1-2cm (in X, Y and Z). This data (delta X, delta Y, delta Z) is directly available at the end of the station setup and must be validated (Apply Button) by the user.

We tried to check the results given by the software for the process of the station coordinates by resection or traversing measurements, but unfortunately in the current version the horizontal and vertical angles are not given by the software. By performing traverse measurements (polygonization computation) and closure, we stated that no global adjustment is done. The outcome is that coordinates of the stations may lightly change, depending on the sequence adopted for the process of the stations.

After the station setup, we usually compute a panoramic image to document the station (fig. 13) and to select by rectangular or polygonal framing the different objects to scan.

The following illustrations show some examples from this project. Post-processing work in Realworks software is still in progress and not discussed in this paper.

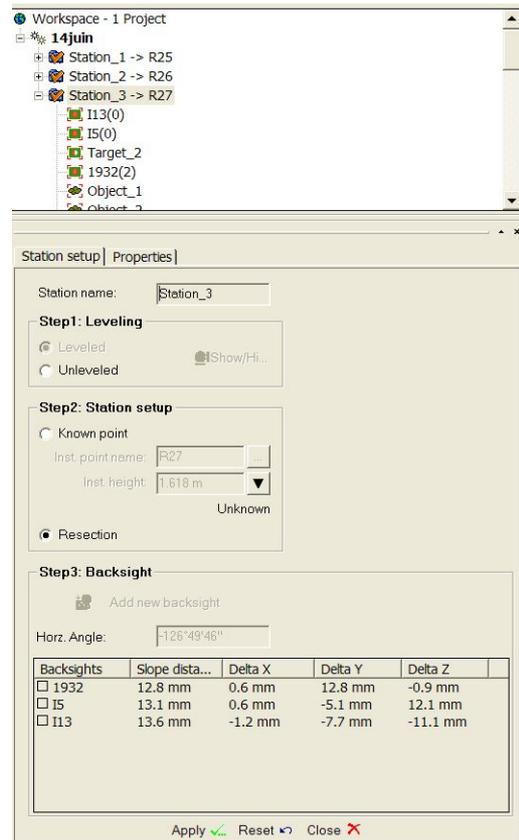


Fig. 12. Station setup (resection mode) in Pointscape software



Fig. 13. Panoramic image computed from the video of the scanner



Fig. 14. Point cloud (raw data) displayed with true color pixels



Fig. 15. Detail of the façade (grey scale intensity image),  
1 point / 1cm



Fig. 16. Overview of the global cloud point after merging all  
objects of the project

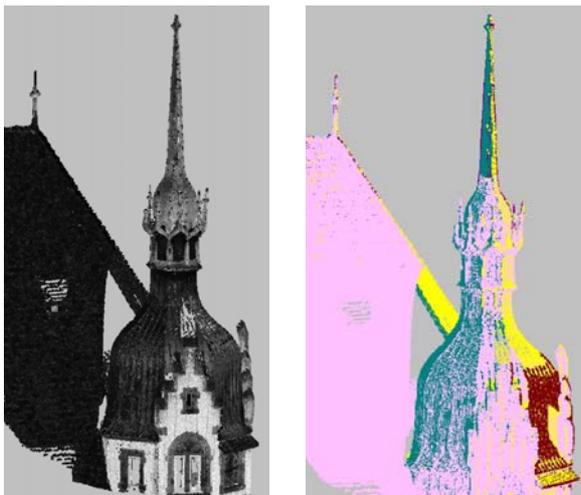


Fig. 17. Visual control of the model by merging objects from  
different stations. By applying the new workflow  
proposed in both Pointscape and Pocketscape  
software and described in §3, we show that only a  
few centimetres separate the corresponding points  
from different scans (for points measured at a  
range of 100m from the scanner station)

## 5. FIRST CONCLUSIONS AND FURTHER INVESTIGATIONS

The Trimble GX Scanner is a powerful new instrument, especially convincing by its small spot and the ability to focus it automatically. This system has been presented as “the 3D scanner that thinks like a surveyor” by introducing a traditional total station survey workflow, up to now uncommon for TLS systems.

For many applications with a lower level of accuracy calibration of the scanner is not necessary. The calibration values are negligible compared with the given accuracies of the measurement. Of course ignoring the calibration is not permitted when one applies TLS in more challenging tasks in the field of engineering surveying.

Trying to calibrate the scanner yields some remarkable facts:

- the distances are biased by an additive constant,
- the two scanners have different additive constants
- the constants depend on the colour of the surface
- measurements to colours with a large constant are of weak intensity and have a high noise.

These first experiences should be further investigated, optimally in collaboration with a specialised physician. Besides that, it should be considered how calibration values could be integrated into the measurement and evaluation procedure. Up to now it is not possible.

The testing of the traditional total station workflow with Trimble’s field software allowing the setup over known points to provide a direct relationship to existing ground control yields very interesting results in terms of versatility and accuracy. All the data measured by the scanner is unfortunately not available in the current release of the software (no angles are displayed, only distances) and should be available for further global adjustments. Homogeneity of cloud points can be viewed in the field by the user without additional post processing of multiple scans to common targets or spheres. The global point cloud from all merged objects is thus directly available for office surveys. More investigations are still in progress to propose methods (not only visual or point to point ones) to evaluate the accuracy of merged objects resulting from this workflow.

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