

Terrestrial laser scanning and digital photogrammetry for cultural heritage - An accuracy assessment

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Outline

- Project
- Terrestrial laser scanning
- Digital photogrammetry
- Total Station
- Comparison – Results
- Conclusions




Terrestrial laser scanning and digital photogrammetry
for cultural heritage: an accuracy assessment

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Project


- Comparison of the 3D accuracies of terrestrial laser scanning versus digital photogrammetry
- For cultural heritage purposes
- Line-of-sight distances < 15 m
- Total station measurements (test set of 100 points) are considered as "truth"

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Project


- Sint-Baafs Abbey (Ghent, Belgium)

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St-Baafs abbey (laserscancloud)




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2008-2009: Pulse laser scanner (Leica scanstation 2)

- Scanning resolution of max. 4 cm
- Laser scanning did not meet photogrammetric accuracies





2010-2011: Phase laser scanner (Leica HDS 6100)

- Different type of laser scanner
- High lateral scanning resolution (< 5 mm)




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▪ Leica ScanStation 2

Time-of-Flight
Pulse-Based
Up to 50 000 pts/sec








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Leica ScanStation 2 Prestatie Specificaties	
Instrumenttype	Puls, dubbelassige compensator, laser scanner met zeer hoge snelheid, millimeternauwkeurig, groot bereik en volledig rondom zicht
Bediening	Laptop of Tablet PC
Camera	Geïntegreerde digitale camera met hoge resolutie
Nauwkeurigheid van individuele meting	Positie* 6 mm Afstand* 4 mm Hoek (horizontaal/verticaal) 60 µrad/60 µrad (3,8 mgon/3,8 mgon) **
Spot grootte	Vanaf 0 – 50 m : 4 mm (FWHH-gebaseerd); 6 mm (Gauss-gebaseerd)
Gemodeleerd vlak precisie/ruis	2 mm **
Meting op richtmerk	2 mm std. afwijking
Dubbelassige compensator	Resolutie 1", dynamisch bereik +/- 5'
Data integriteit bewaking	Periodieke zelftest tijdens de werking en opstarten
Laser scan systeem	Bereik 300 m bij 90%; 134 m bij 18% reflectie Scan snelheid Tot 50,000 punten/sec, maximale snelheid Gemiddeld: afhankelijk van specifieke scandichtheid en blikveld Scandichtheid < 1 mm max, over volledig bereik; volledig instelbare horizontale en verticale resolutie; 1 enkel punt aanwijsoptie
Laser klasse	3R (IEC-60825-1), zichtbaar groen
Verlichting	Volledig werkzaam bij zowel helder zonlicht als absolute donker
Voeding	36 V; AC of DC; hot swappable


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▪ Leica HDS6100

Phase-Based

Up to 500 000 pts/sec



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for cultural heritage assessment

November 17-19, 2009

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Key Leica HDS6100 Performance Specifications	
Instrument type	Compact, phase-based, dual-axis sensing, ultra-high speed laser scanner, with survey-grade accuracy and full field-of-view
User interface	Onboard touch panel, or external notebook or Tablet PC, or PDA
Data storage	Integrated hard drive
Accuracy of single measurement	Position 5 mm, 1 m to 25 m range; 9 mm to 50 m range Distance ≤2 mm at 90% albedo up to 25 m; ≤3 mm at 18% albedo up to 25 m ≤3 mm at 90% albedo up to 50 m; ≤5 mm at 18% albedo up to 50 m Angle (Horizontal/vertical) 125 µrads/125 µrads (7.9 mgon/7.9 mgon) one sigma
Spot size	3 mm at exit (based on Gaussian definition) + 0.22 mrad divergence; 8 mm @25 m; 14 mm @50 m;
Modeled surface precision**/noise	1 mm at 25 m; 2 mm at 50 m, for 90% albedo; one sigma 2 mm at 25 m; 4 mm at 50 m, for 18% albedo; one sigma
Target acquisition***	2 mm std. deviation
Dual-axis sensor	Selectable on/off; Resolution 3.6"
Laser scanning system	Range 79 m ambiguity interval 79 m @90%; 50 m @18% albedo Scan Rate Up to 508,000 points/sec, maximum instantaneous rate Scan density @10 m @50 m "Preview" 50.6 x 50.6 mm 250 x 250 mm Middle (4x) 12.6 x 12.6 mm 62 x 62 mm High (8x) 6.3 x 6.3 mm 31.4 x 31.4 mm Super High (16x) 3.1 x 3.1 mm 15.8 x 15.8 mm Ultra High (32x) 1.6 x 1.6 mm 7.9 x 7.9 mm
Laser Class	3R (IEC 60825-1)
Lighting	Fully operational between bright sunlight and complete darkness
Power supply	24 V DC; integrated Li-ion battery (2.5 hrs) and/or optional external DC power supply (4 hrs) or AC supply
Power consumption	65 W max.
Temperature	Operation: -10° C to +45° C; Storage: -20° C to +50° C

All specifications are subject to change without notice All +/- accuracy specifications are one sigma unless otherwise noted
 ** One sigma; subject to modeling methodology for modeled surface *** Algorithmic fit to planar HDS gray & white targets

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Terrestrial laser scanning



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Terrestrial laser scanning

- Phase-based Leica HDS6100
- Average lateral resolution of 0.5 cm
- Intensity value of reflection laser beam
- No RGB color information
- 8 circular targets on tripods

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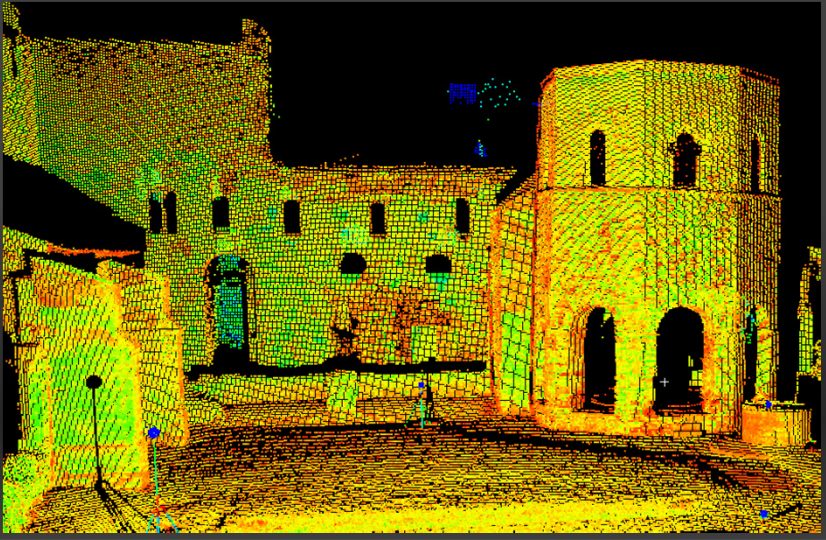
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Terrestrial laser scanning

- Multiple (ca. 30) scanning positions
- Target-based registration
- Georeferencing in Lambert72 (conical projection with Hayford ellipsoid) based on total station / GNSS measurements


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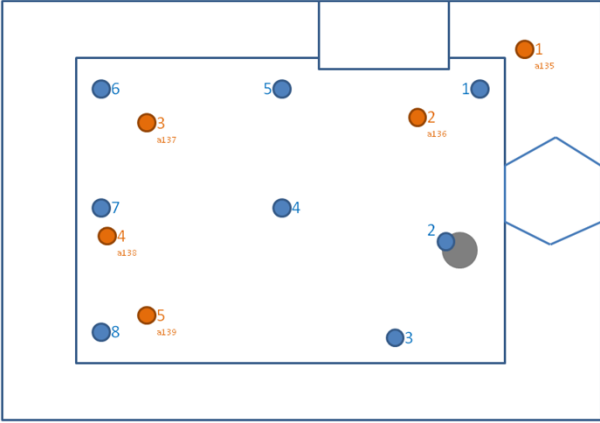


Terrestrial laser scanning

1 ● Target



1 ● Scanpositie

Scanning Sint-Baafsabdij 07/12/2010
HDS6100




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Digital photogrammetry

- Camera:
- Canon Eos 1Ds (11 Mp) full frame DSLR
- with 24 mm lens (grand angular)
- approx. scale of 1/500
- pixel size approx. 3-5 mm


- Minimum 80% overlap

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Digital photogrammetry

- Photogrammetric processing of the stereo couples using **Virtuoso** software
- **Relative** orientation:
 - 100 – 150 homological points per couple
 - Maximum error: ca. 1/5 of a pixel (ca. 1mm)
- **Absolute** orientation:
 - based on total station / GNSS measurements in Belgian Lambert72 conical projection
 - Maximum RMS error: 1 cm (X, Y and Z)

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Digital photogrammetry

Photogrammetric products: DEM and Orthorectified images







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Total station

- Georeferencing laser scanning
- Absolute orientation photogrammetry
- Independent test set of 100 points
- 'Ground truth' for comparison




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Comparison – Results


- **Differences** between X-, Y- and Z-coordinates of test set (cm) for
 - Photogrammetry vs. total station
 - Laser scanning vs. total station
 - Photogrammetry vs. laser scanning

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Systematic errors



Comparison of systematic errors in the position of the control points using laser scanning and photogrammetry compared to total station measurements

	Systematic error (cm)		
	(Average of algebraic error values)		
	X	Y	Z
Photogrammetry vs. Total station	-1,00	-0,30	-1,57
Laser scanning vs. Total station	0,90	-0,53	0,27
Photogrammetry vs. Laser scanning	-1,90	0,20	-1,83


- Photogr. vs. total station => 1.9 cm (3D)
- Laser scanning vs. total station => 1.1 cm (3D)
- Altimetric error photogrammetry ca. 5 times higher than the altimetric error of laser scanning

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Random errors



Comparison of accuracies (random errors) in the position of the control points using laser scanning and photogrammetry compared to total station measurements

	Random error (cm)		
	(Average of absolute error values)		
	X	Y	Z
Photogrammetry vs. Total station	2,73	2,90	3,07
Laser scanning vs. Total station	1,53	1,73	1,30
Photogrammetry vs. Laser scanning	3,03	3,63	3,20


- Photogr. vs. total station => 5.0 cm (3D)
- Laser scanning vs. total station => 2.6 cm (3D)
- Altimetric error photogrammetry 2 times higher than the altimetric error of laser scanning

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Conclusions

- Higher systematic and random error for photogrammetry (error in Z of photogrammetry even 2-5 times higher than laser scanning).
- In this cultural heritage test case with lines of sight of 5 -15 m: Lateral scanning resolution of 0.5 cm enables to surpass the accuracy of digital photogrammetry with the same resolution.

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Thank you for your attention

Questions ?

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