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Geometric Accuracy Investigations of the Latest Terrestrial Laser Scanning Systems

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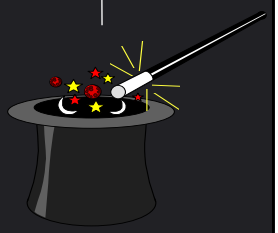
Outline of presentation



- Introduction
- Laser scanning systems tested
- 3D test field (VDI/VDE 2634)
- Distance measurement
- Inclination sensor
- Influence of the laser beam's angle of incidence on 3D accuracy
- Conclusions & outlook

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Introduction

- New features, improved accuracy
- Different methods
- Different standards
- Development of testing procedures

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Terrestrial laser scanners tested

Leica ScanStation 1

Leica ScanStation 2

Leica HDS6000

Riegl LMS420i

Faro LS880

Zoller + Fröhlich Imager 5006

Trimble GX

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Technical specification

Scanner / feature		Trimble GX	Leica ScanStation 1	Leica ScanStation 2	Riegl LMS420i
Distance measurement		Time-of-flight			
Field of view [°]		360 x 60	360 x 270	360 x 270	360 x 80
Range [m]		200	300	300	< 1000m
Laser class		2, 3R	3R	3R	1
Scan speed [pts/s]		≤ 5 000	≤ 4 000	≤ 50 000	≤ 12 000
Angular resolution [°]	vertical	0,0017	0,0017	0,0017	0,002
	horizontal	0,0017	0,0017	0,0017	0,0025
3D single point accuracy		12mm/100m	6mm/50m	6mm/50m	10mm/50m
Camera		integrated	integrated	integrated	extern / option
Inclination sensor		Compensator	Compensator	Compensator	optional

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Technical specification (cont.)

Scanner / feature		FARO LS880	Leica HDS 6000	Z+F IMAGER 5006
Distance measurement		Phase difference		
Field of view [°]		360 x 320	360 x 310	360 x 310
Range [m]		< 76	< 79	< 79
Laser class / output [mW]		3R / 20	3R / 29	3R / 29
Scan speed [pts/s]		≤ 120 000	≤ 500 000	≤ 500 000
Angular resolution [°]	vertical	0,009	-	0,0018
	horizontal	0,009	-	0,0018
3D single point accuracy		-	6mm/25m	-
Camera		extern / option	extern / option	extern / option
Inclination sensor		yes	Yes	yes

3D test field

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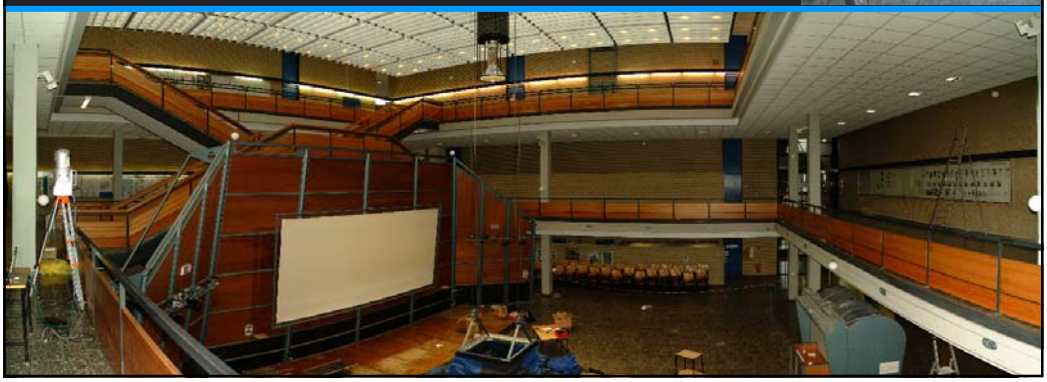
- Investigation into 3D accuracy (VDI/VDE 2634 Part II, III)
- Test field: 43 reference points, 3D precision < 1mm
- Large volume: 30x20x12m³



3D test field

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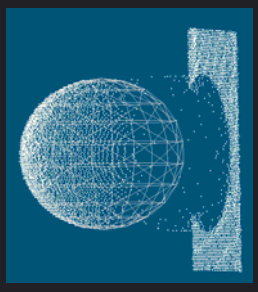
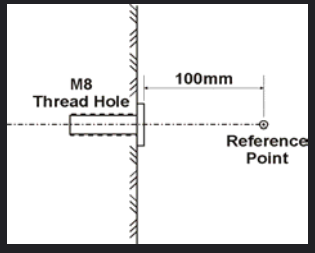
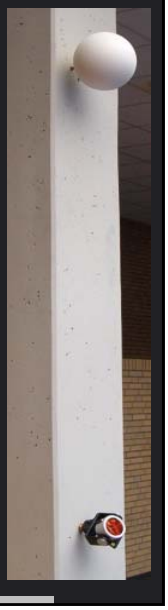
- Test bodies: spheres, diameter 145mm / 199mm
- Scanning of spheres from 5 stations
- Computation of 3D distances between reference points in all combinations
- Up to 780 distances with different directions in space







3D test field

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- Comparison: Scanner distances vs. reference

```
7102        7106      23,0426      23,0539     0,0113
7102        7107      16,6363      16,6304    -0,0059
7102        7108       8,9669       8,9530    -0,0139
7103        7104      21,8998      21,9087     0,0089
7103        7105      23,5719      23,5863     0,0144
7103        7106      27,1186      27,1352     0,0167
7103        7107      20,1078      20,1055    -0,0023
7103        7108      14,3976      14,3934    -0,0042
7104        7105       8,3929       8,3943     0,0015
7104        7106      15,6567      15,6592     0,0025
7104        7107      14,1055      14,0903    -0,0152
7104        7108      19,8454      19,8407    -0,0046
7105        7106       7,2638       7,2648     0,0010
7105        7107       8,9014       8,8870    -0,0143
7105        7108      16,5722      16,5707    -0,0015
7106        7107       9,4487       9,4432    -0,0055
7106        7108      16,8890      16,8903     0,0013
7107        7108       8,9483       8,9511     0,0028

STATISTIK
StreckeMin = 1,5643; StreckeMax = 33,1000
dMin = -0,0160; dMax = 0,0313
dMit = 0,0056; dMitAbs = 0,0070
nNeg = 153; nPos = 627; nGes = 780

LEGENDE
d           = StreckeRef - StreckeGem;
dMax        = Maximaler Wert von d;
dMin        = Minimaler Wert von d;
dMit        = Summe ( d ) / nGes;
dMitAbs     = Summe ( | d | ) / nGes;
nGes        = Anzahl d gesamt;
nNeg        = Anzahl d negativ;
nPos        = Anzahl d positiven incl. 0;
StreckeGem  = Berechnete Strecke im gemessenen System;
StreckeRef  = Berechnete Strecke im ReferenzSystem;

___ JGeoPro, Version: 7.3.25x, HafenCity Universität Hamburg, Department Geomatik
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3D test field

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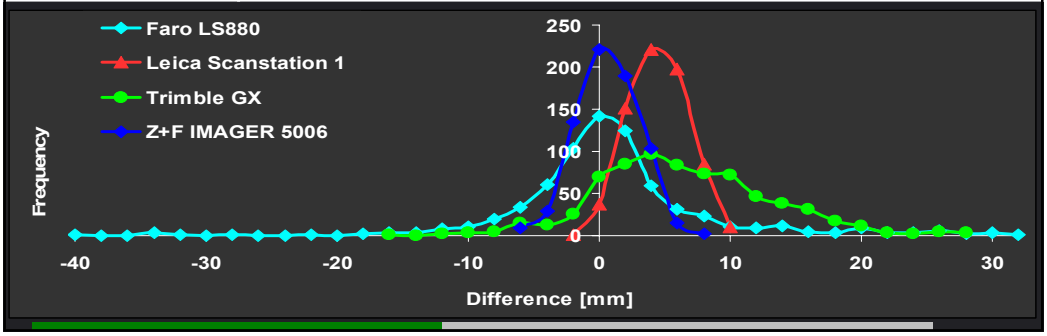
- Results from test campaign March 2007

Scanner	# 3D points	# distances	Δl min [mm]	Δl max [mm]	span min/max [mm]	syst. shift [mm]
Leica ScanStation 1	38	703	-2,3	9,2	11,5	3,6
Z+F IMAGER 5006	38	703	-7,4	6,6	14,0	-0,3
Trimble GX	38	703	-16,0	27,6	43,6	6,0
Faro LS 880 HE	38	703	-41,1	30,7	71,8	0.1



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3D test field

- Results from test campaign October & December 2007

Scanner	test campaign	# 3D points	# distances	Δl min [mm]	Δl max [mm]	span min/max [mm]	syst. shift [mm]
Leica ScanStation 1	Oct. 2007	29	351	-5,4	6,5	11,9	0,7
Leica ScanStation 2	Oct. 2007	29	351	-5,4	6,5	11,9	2,2
Leica HDS6000	Oct. 2007	30	406	-6,7	6,3	13,0	-0,2
Z+F IMAGER 5006	Oct. 2007	30	406	-5,7	7,7	13,4	0,4
Riegl LMS420i	Dec. 2007	29	351	-19,8	6,5	26,3	-6,3

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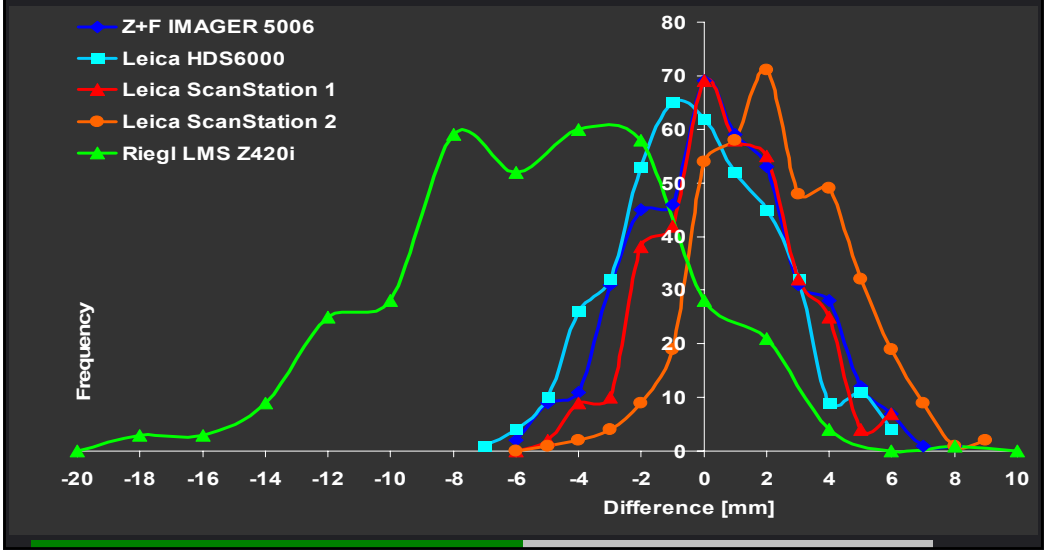
3D test field

- Results from test campaign October & December 2007



Distance measurement

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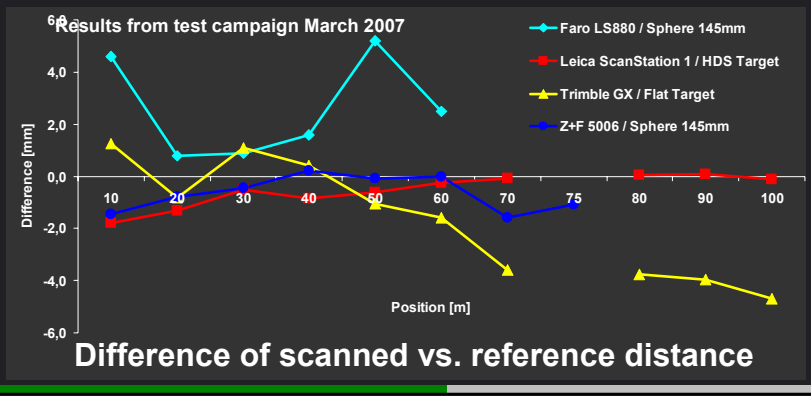
- Comparison of scanned vs. reference distances (EDM)
- Scanner targets: spheres / planar targets
- Scanned distances: average of 3 scans
- Field conditions!



Difference of scanned vs. reference distance

Distance measurement

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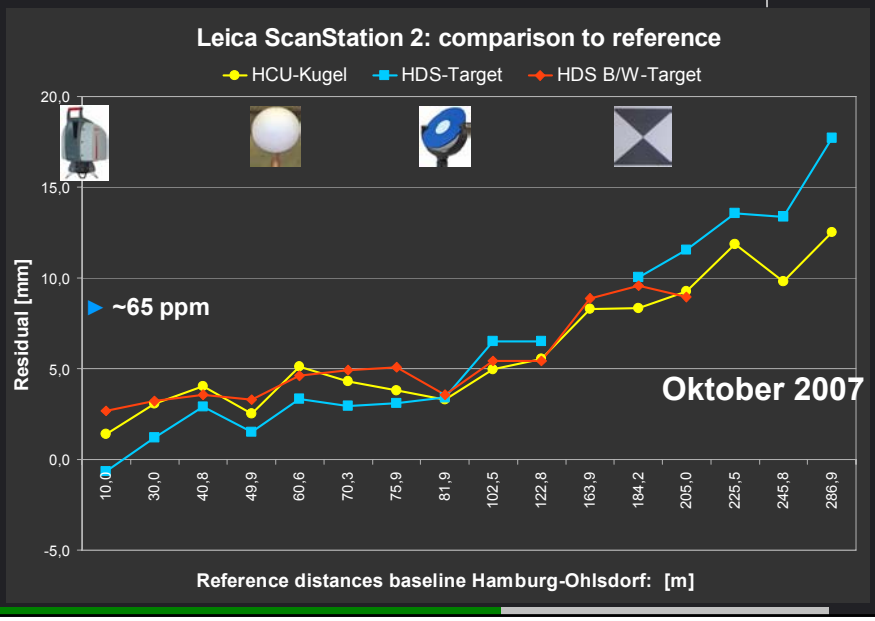

Distance measurement

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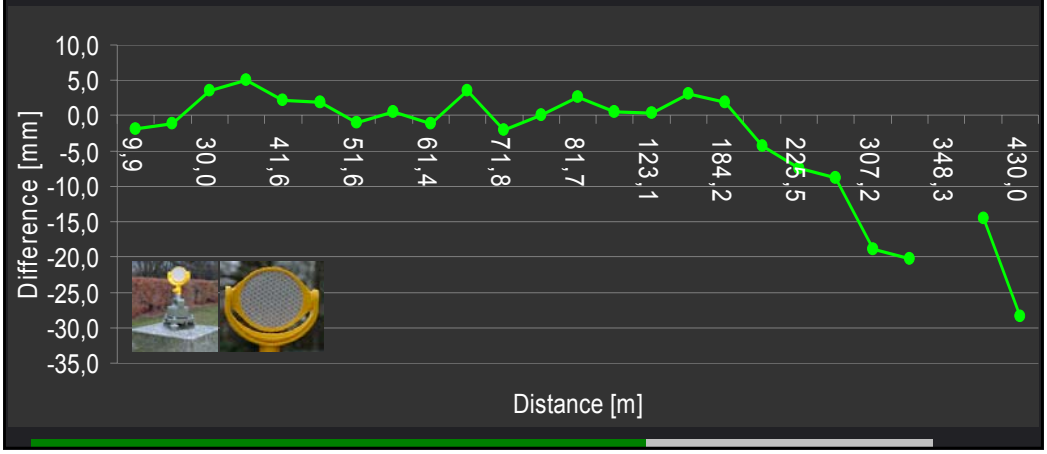
- Results from test campaign October 2007
  Riegl LMS 420i



Inclination sensor & tumbling error

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- 12 spheres distributed on the circumference of a horizontal circle (r = 50m)
- 3 (5) scans / sphere with highest resolution
- Monitoring of tripod movements by Leica Nivel20
- Condition: all spheres should lie in one plane
- Scanners with inclination compensation: z = const.!

Inclination sensor

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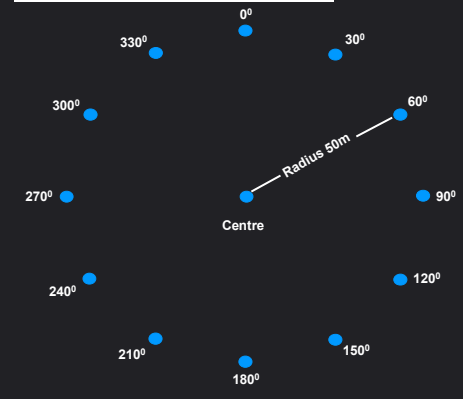

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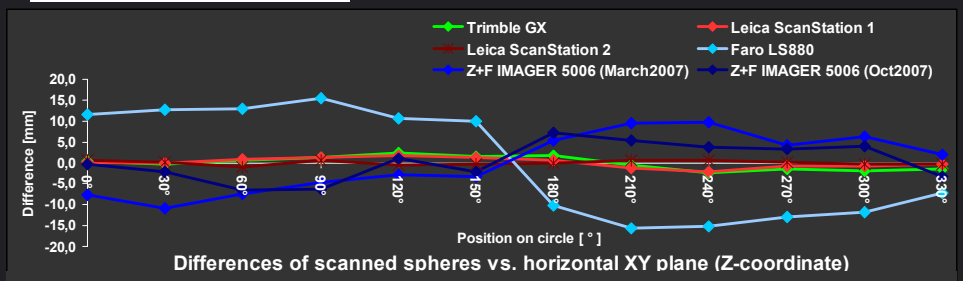
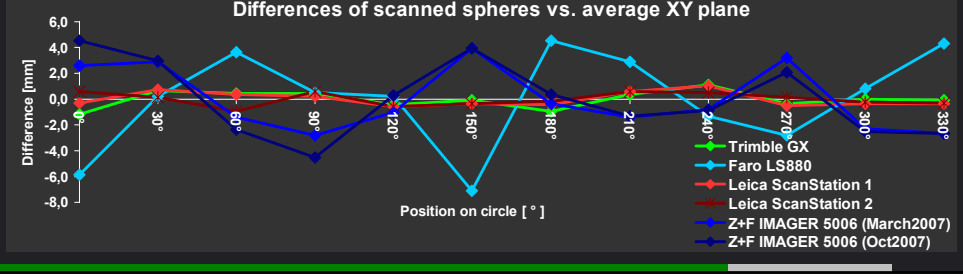
Inclination sensor



Differences of scanned spheres vs. horizontal XY plane (Z-coordinate)

Differences of scanned spheres vs. average XY plane



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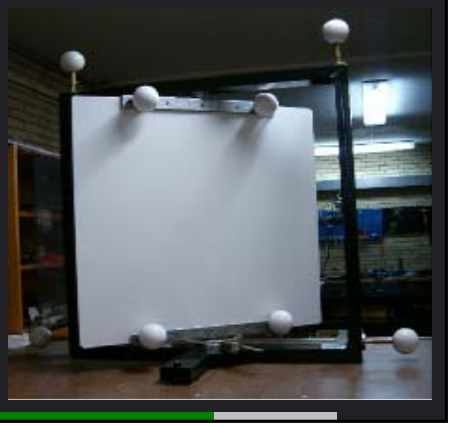
Influence of the laser beams angle of incidence on 3D-accuracy

- Test body: swivelling planar stone slab
- Scanning of the stone slab in 10 angular positions
- Resolution: 3mm
- Reference: 4 spheres mounted on stone slab
- Postulation: spacing of averaging planes through centre of spheres and point cloud should be constant!



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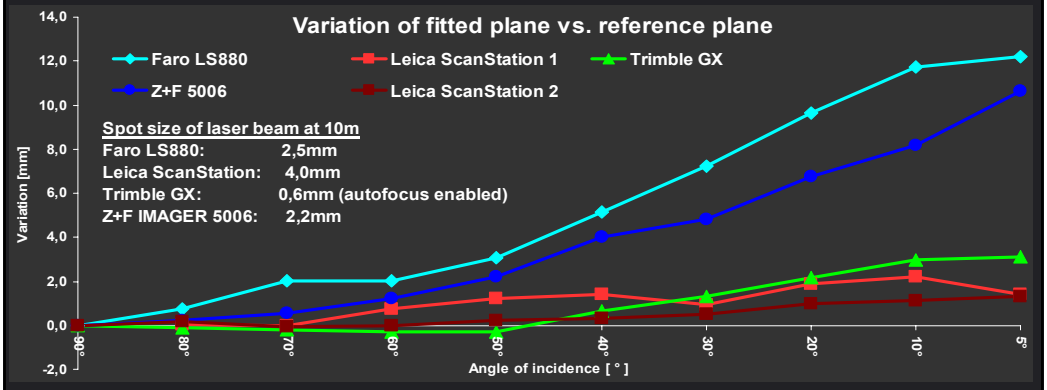
Influence of the laser beams angle of incidence on 3D-accuracy



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Conclusions and outlook

- Results of investigations = ± specs of manufacturer
- Test field: ‚realistic' volume
- ‚Circle': new approach on investigations on inclination sensor & tumbling error
- Critical aspect: ratio range of scanner to size of target
- Standardized tests, test bodies, calibration & formats?
- Single point measurement?
- Competition between laser scanners and total station?

Thank you very much for your attention!