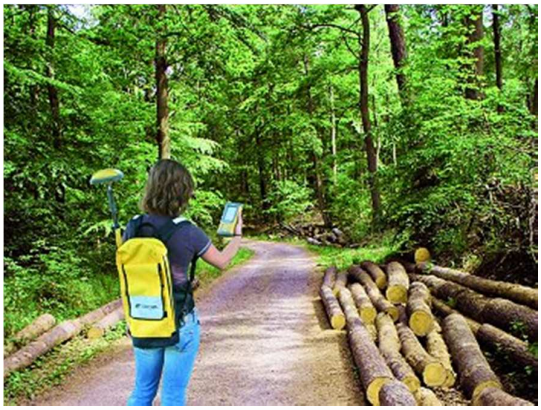
Agricultural Forest Applications and Boundary Surveys Using Low-cost High Sensitivity GPS (HS-GPS) Receivers

Severin Heuboeck and Guenther Retscher
Department of Geodesy and Geoinformation
Vienna University of Technology

Motivation

- GNSS use in forests
  - Logistic chains for wood processing
  - Machine guidance
  - GIS
  - Boundary survey
  - Leisure activities
  - Navigation
  - …



Advantages of HS-GPS

- Weaker signals can be detected due to:
  - Integration time < 1ms
  - Detectable signal strength > -180dBW
- Higher availabity in urban canyons or forests

and / or

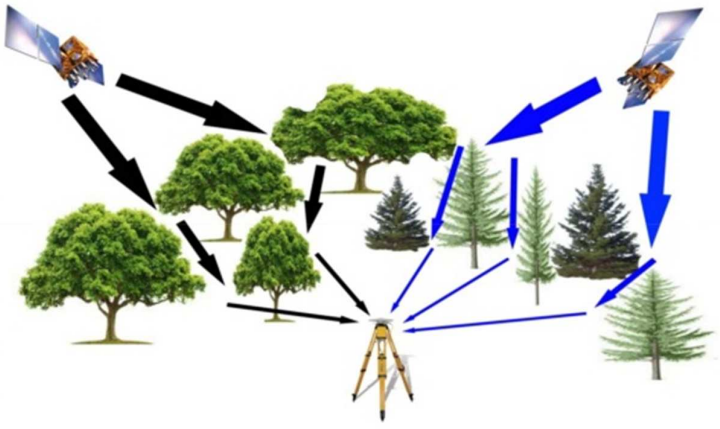
- Higher positioning accuracy
- Possibility to store raw data
- More processing power
- GNSS ability

Challenges

Typical signal propagation in forests

Signal is:

- scattered
- damped
- reflected
- delayed



Each gain in availibility may result in a loss of accuracy

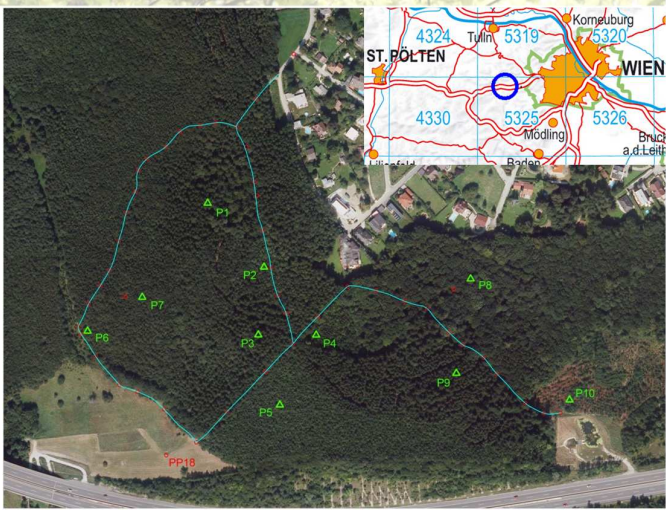
Study Goals

Evaluation of performance and practicability of single frequency HS-GPS receiver under forest canopy

- Code Single Point Positioning (SPP)
- Single Frequency Baseline Measurement to a virtual reference station in a CORS network

Test Area and Equipment

- Mixed forest near Vienna
- Forest classification:
  - Broad-leaved forest
  - Needle forest
  - Young forest
- 10 control points
- 1 reference point under open sky



- Low-cost receiver: u-blox LEA-6T
  - 2 Mio. correllators
  - TTFF < 1 sec.
  - Signal acquisition down to -178 dBW

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Field Tests

- Observations over a whole vegetation cycle
- 3 campaigns:
  - Early summer
  - Autumn
  - Winter
- Measurement duration: 24h
- Data storage on laptop

Results Code SPP

- SPP with receiver software

Summer	Broad-leaved		Needle		Young forest	
[m]	horiz.	vert.	horiz.	vert.	horiz.	vert.
Mean	0.66	12.91	0.42	11.45	0.87	4.38
Std. dev.	8.31	10.19	7.90	9.39	7.45	8.24

- Standard deviation: ~ 8 m (horizontal)
- Height deviations are much higher
- Useable for navigation

Autumn	Broad-leaved		Needle		Young forest	
[m]	horiz.	vert.	horiz.	vert.	horiz.	vert.
Mean	1.97	15.80	1.09	13.82	2.23	8.34
Std. dev.	7.54	8.81	7.13	8.19	7.42	7.78

- Strongest influences of the foliage in young forest
- Dry leaves influence more than fresh soaked leaves

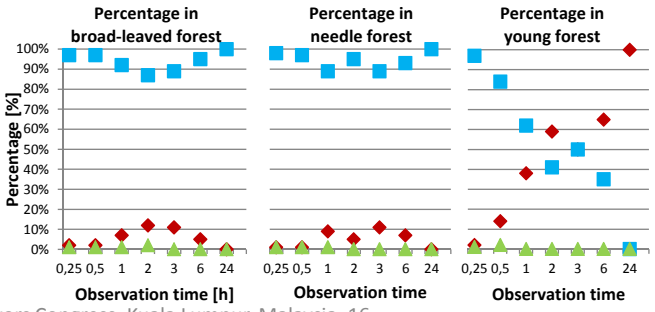
Winter	Broad-leaved		Needle		Young forest	
[m]	horiz.	vert.	horiz.	vert.	horiz.	vert.
Mean	0.18	14.07	0.58	8.98	0.65	4.82
Std. dev.	7.38	8.93	5.95	7.19	5.27	5.99

Results Baseline Solutions

Differential Observations with varying observation times

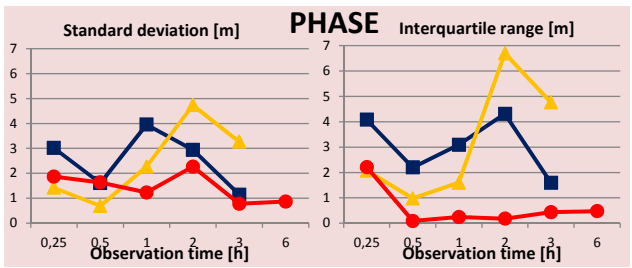
Summer	15 min.		30 min.		1 h		2 h		3 h		6 h	
[m]	horiz.	vert.	horiz.	vert.	horiz.	vert.	horiz.	Vert.	horiz.	vert.	horiz.	vert.
Mean	1.06	12.19	3.50	-7.43	2.29	1.32	3.36	-15.96	3.77	-11.545	2.63	6.39
Std. Dev.	254.42	471.44	148.97	345.83	39.11	164.32	43.92	208.7	53.23	254.367	31.44	41.71
Median	0.16	1.77	0.14	1.54	0.07	1.52	0.07	1.33	0.02	1.124	0.03	1.07
IQR	4.32	6.13	4.67	6.03	4.97	6.28	4.93	4.63	3.49	5.684	4.02	4.28

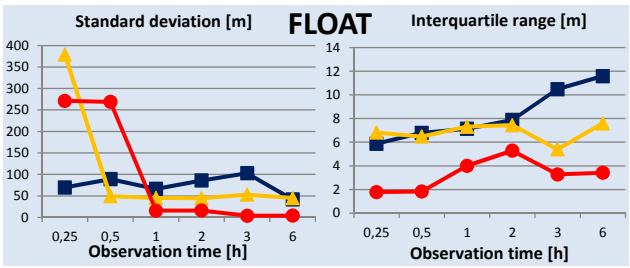
- Many outliers cause high standard deviations
- No normal distribution
- Median and interquartile range show the possibilities of baseline solutions
- Percentage of phase solutions (red) in high forest max. 12 %
- Float solutions (blue) are dominant
- Nearly no code solutions (green)



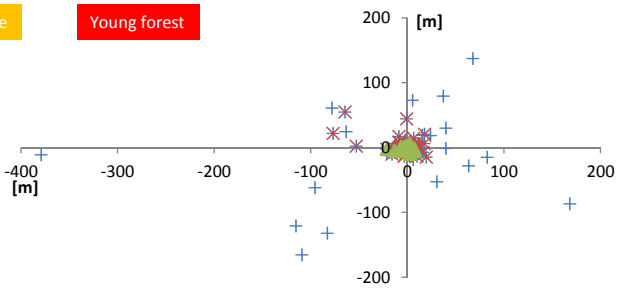
Results Baseline Solutions

- Analysis of phase and float solutions





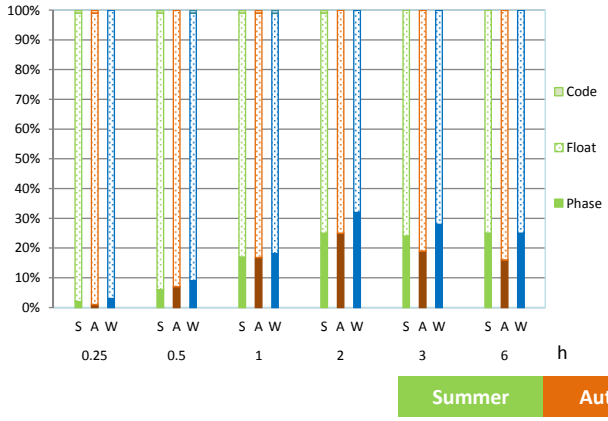
Broad-leaved Needle Young forest

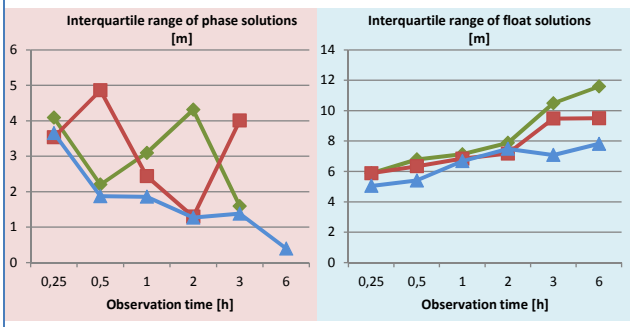


- Outliers can be seen in the float solutions
- Robust filters reduce the influence

Results Baseline Solutions

Performance in different seasons





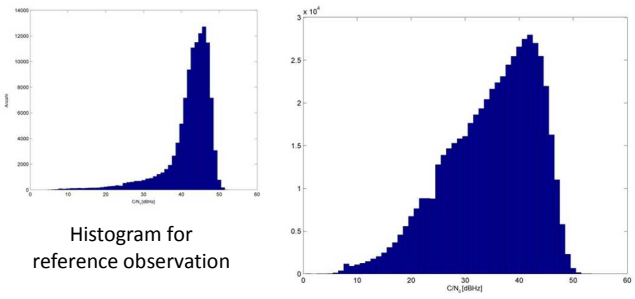
Summer | Autumn | Winter

Lower percentage of phase solutions in autumn

Different behaviour of phase and float solutions in broad-leaved forest

Statistical Analysis of Raw Data

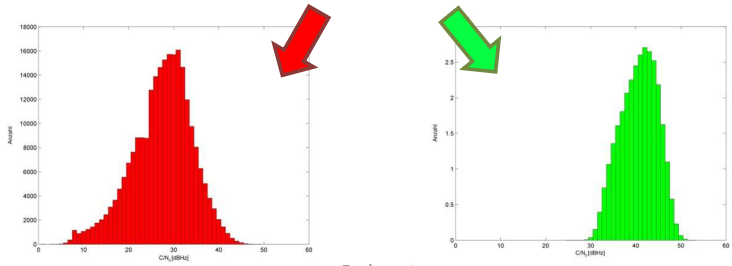
- C/N_0 distributions as a measure of signal strength
- Percentage of Loss of Lock-Indicator (LLI) shows signal quality



Histogram for reference observation

Histogram of C/N0 distribution seperates into two sub-quantities:

1) Unaffected signals without LLI (green)
2) Affected signals with LLI (red)



In high forests about half of the satellite observations are flagged with a LLI flag

Conclusions and Outlook

- Code SPP is useable for navigation (height critical)
- Single frequency baseline observations are possible but highly affected by the canopy
- In average only half of the satellite observations are useable for positioning
- By the increasing number of GNSS
- satellites the performance of relative positioning in forests is expected to be higher
- Evaluation of different geodetic and navigation receivers is under progress

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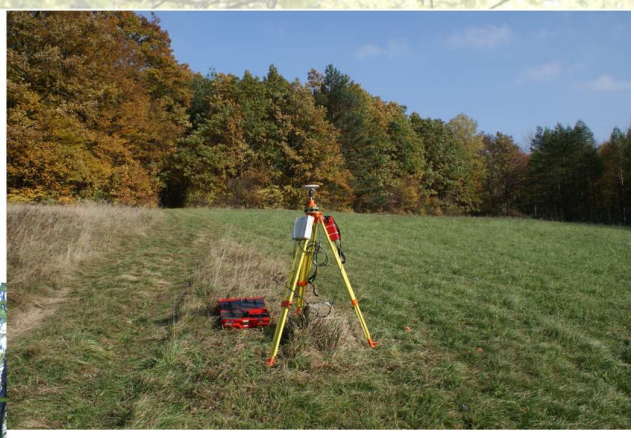

Your attention!