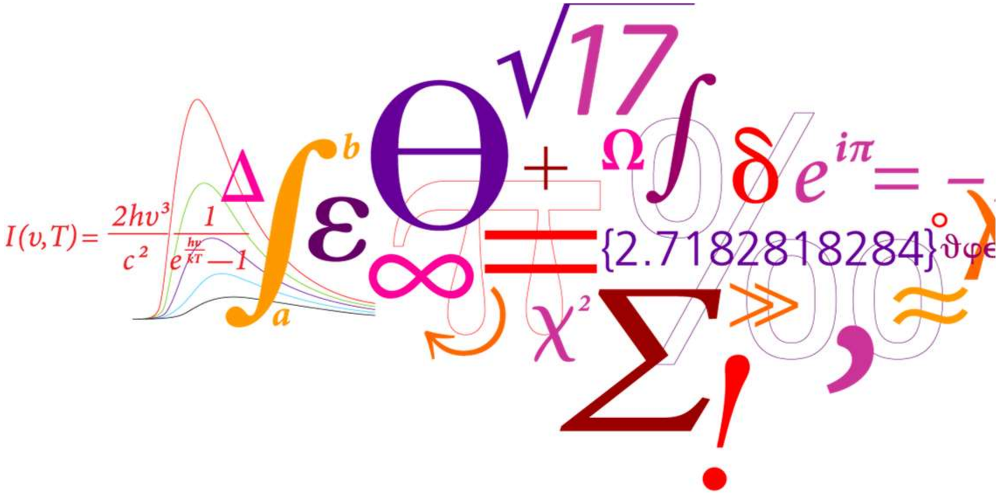
Positioning and application of drones – research at DTU

Daniel Olesen,
Dept. of Geodesy



DTU Space
Institut for Rumforskning og -teknologi

Selected topics

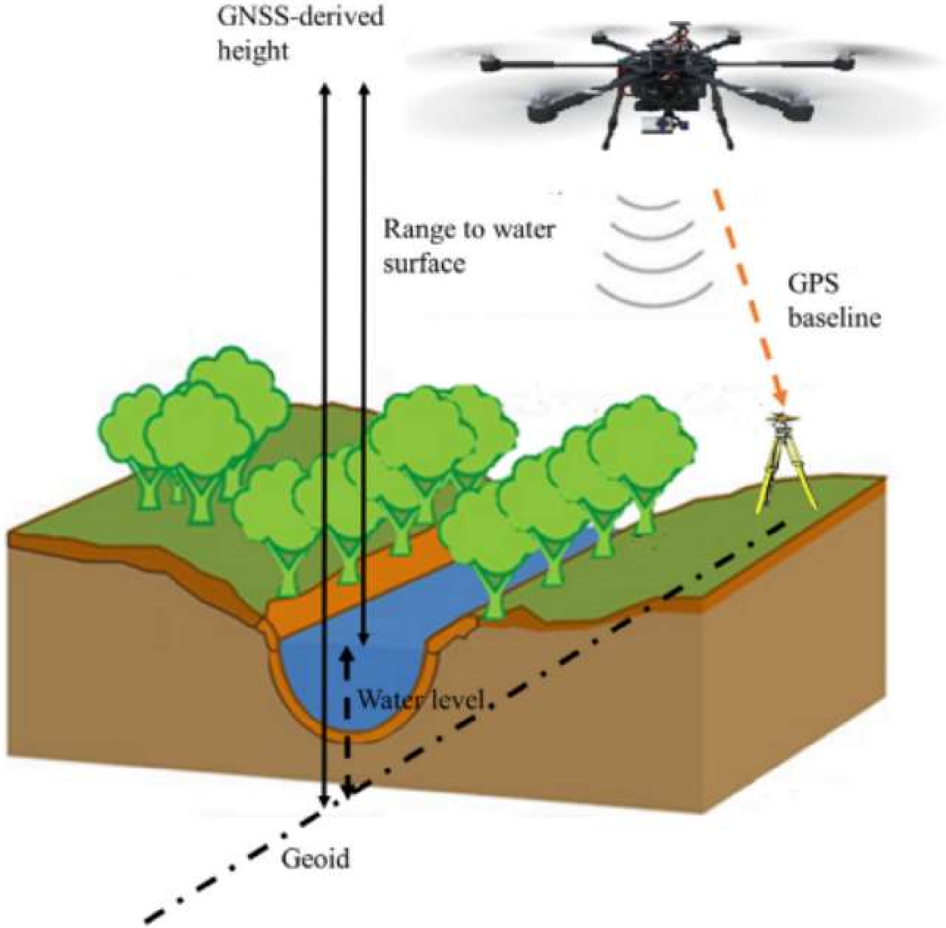
- **Ultra-tight GNSS/INS integration for positioning of UAVs in forested areas**
  - Motivation: Hydrology (water-level) measurements using a radar and GNSS-derived height in Mexican cenote shadowed by vegation
  - PhD topic of **Daniel Olesen** (2014-17)

- **Relative (vision-based) pose estimation of magnetometer payload**
  - Motivation: Unexploded Ordnance (UxO) Detection (Magnetometer)
  - Required survey before construction of offshore windmill farms
  - PhD topic of **Xiao Hu** (2017-20)

- Other notable research areas with drones at DTU Space; DEM/DTMs (Photogrammetry and LiDAR), Bathymetry (tethered sonar), Gamma-ray detection, Soil-moisture retrieval (Hyper-spectral camera), Laser-spectroscopy

Motivation/Background (UAV water-level measurements)

- Background for the PhD study was a UAV water-ranging application
- Collaboration between DTU Environment and DTU Space
- Distance from UAV to water surface is measured by commercial radar
- Test platform: DJI S900 Spreading Wings Hexacopter (Payload cap. 1,5 kg.)
- Initial surveys was based on **<u>GNSS</u>** alone



Bandini, Jakobsen, Olesen, Reyna-Gutiérrez and Bauer-Gottwein (2017)

Survey in Mexican cenote

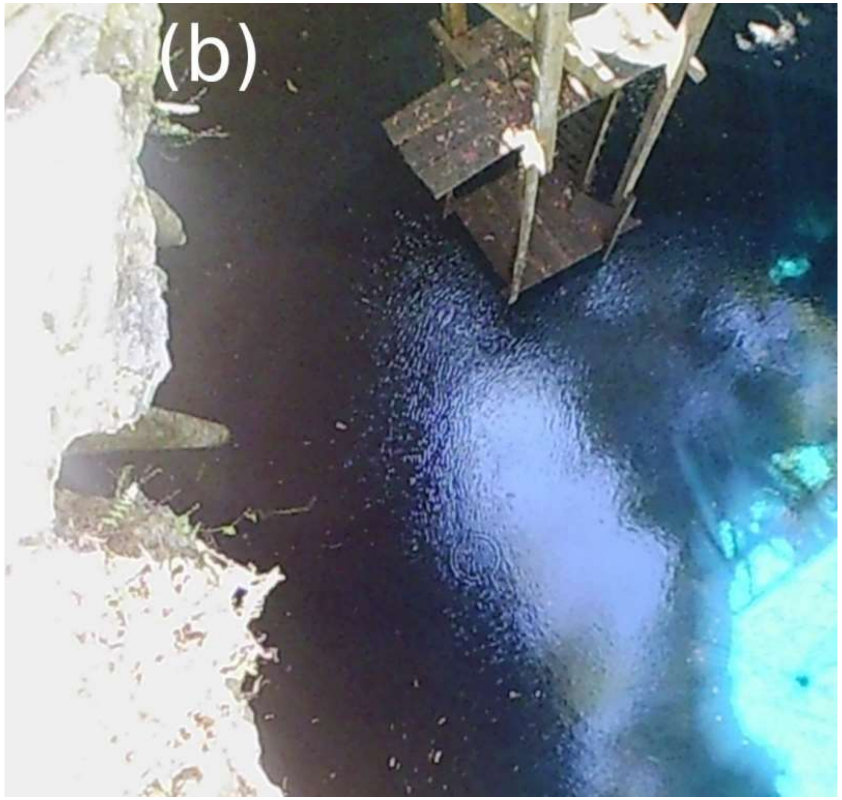
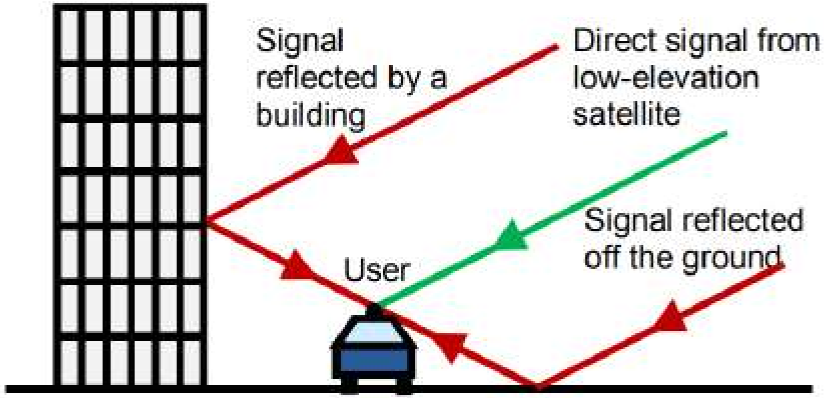


Photo Credits: Filippo Bandini (DTU Environment)

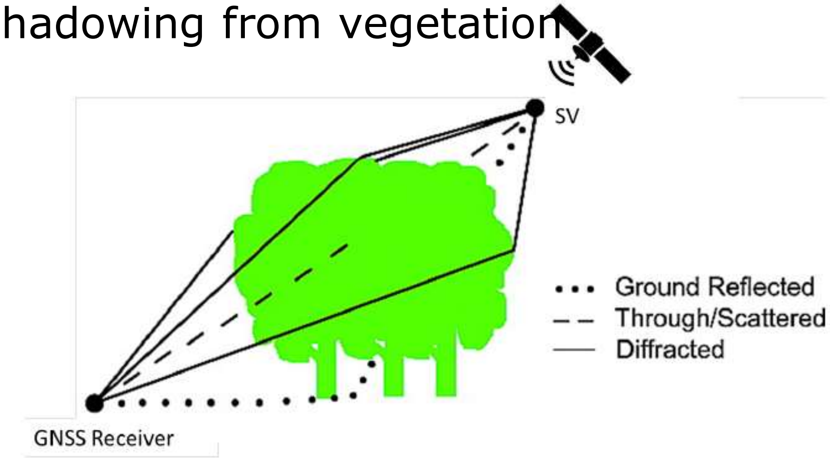
GNSS results was completely useless here!

Limitations in GNSS positioning

Multipath



Shadowing from vegetation



None-Line Of Sight reception

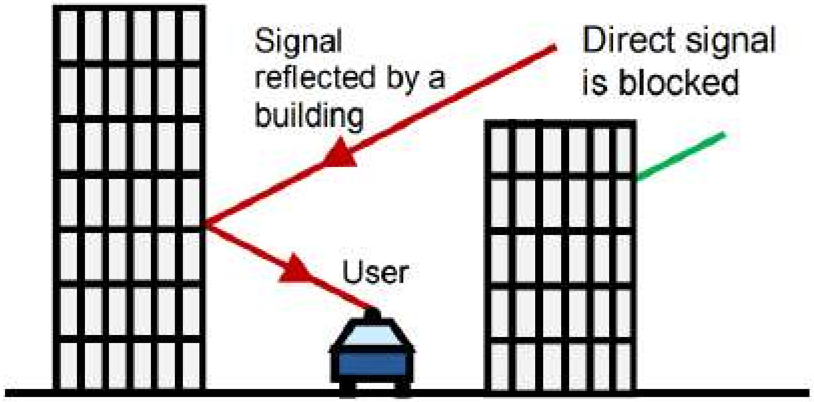
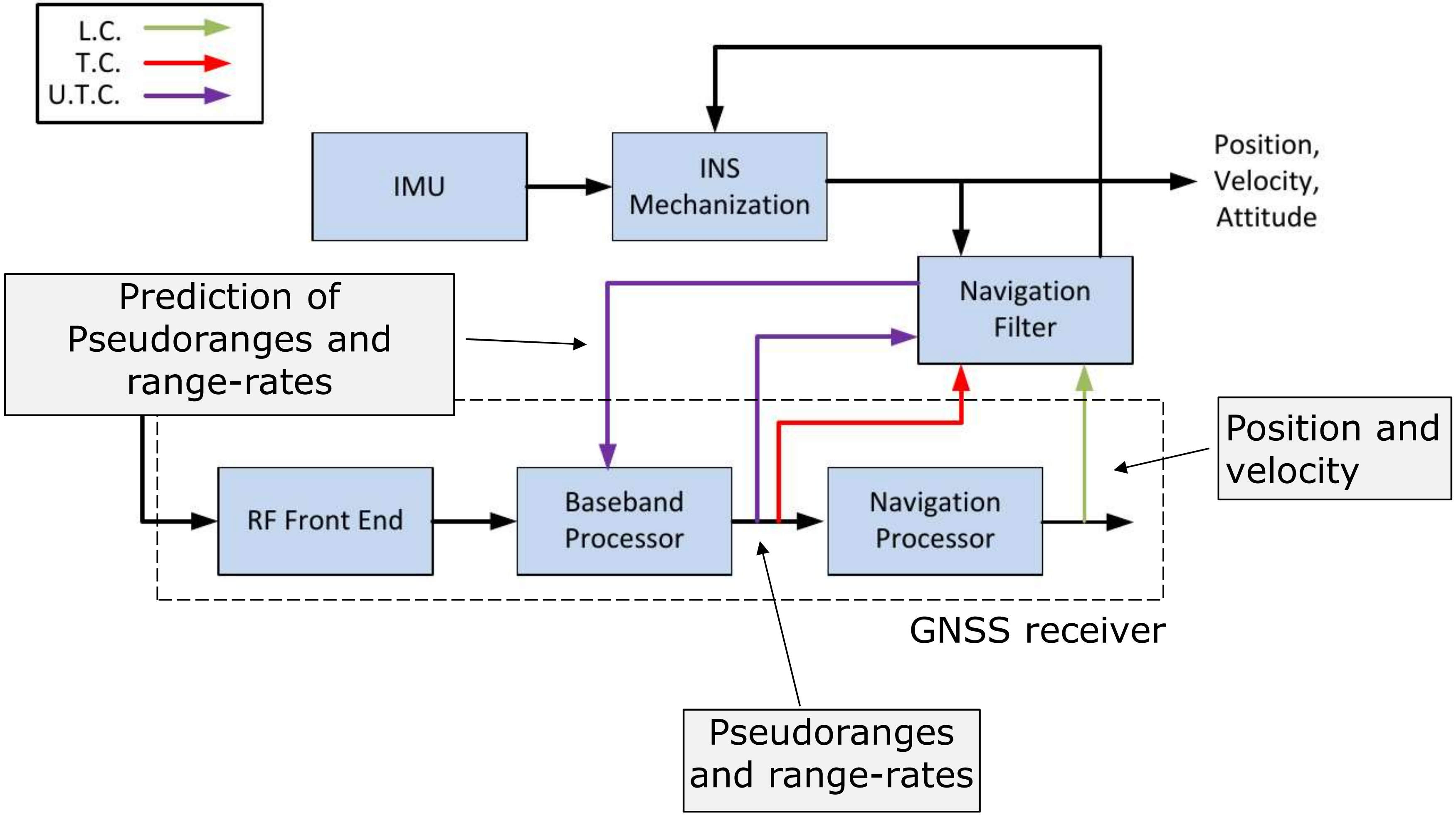


Figure credit: Savage et. al. (2003)

Figure credits: Groves et. al. (2003)

Improve robustness -> GNSS/INS integration



Ultra-tight GNSS/INS on UAVs for navigation in forested areas

- No commercial navigation system of this type is readily available!

- Method have proven to improve GNSS signal reception, interference rejection and positioning accuracies compared to loose- and tight couplings

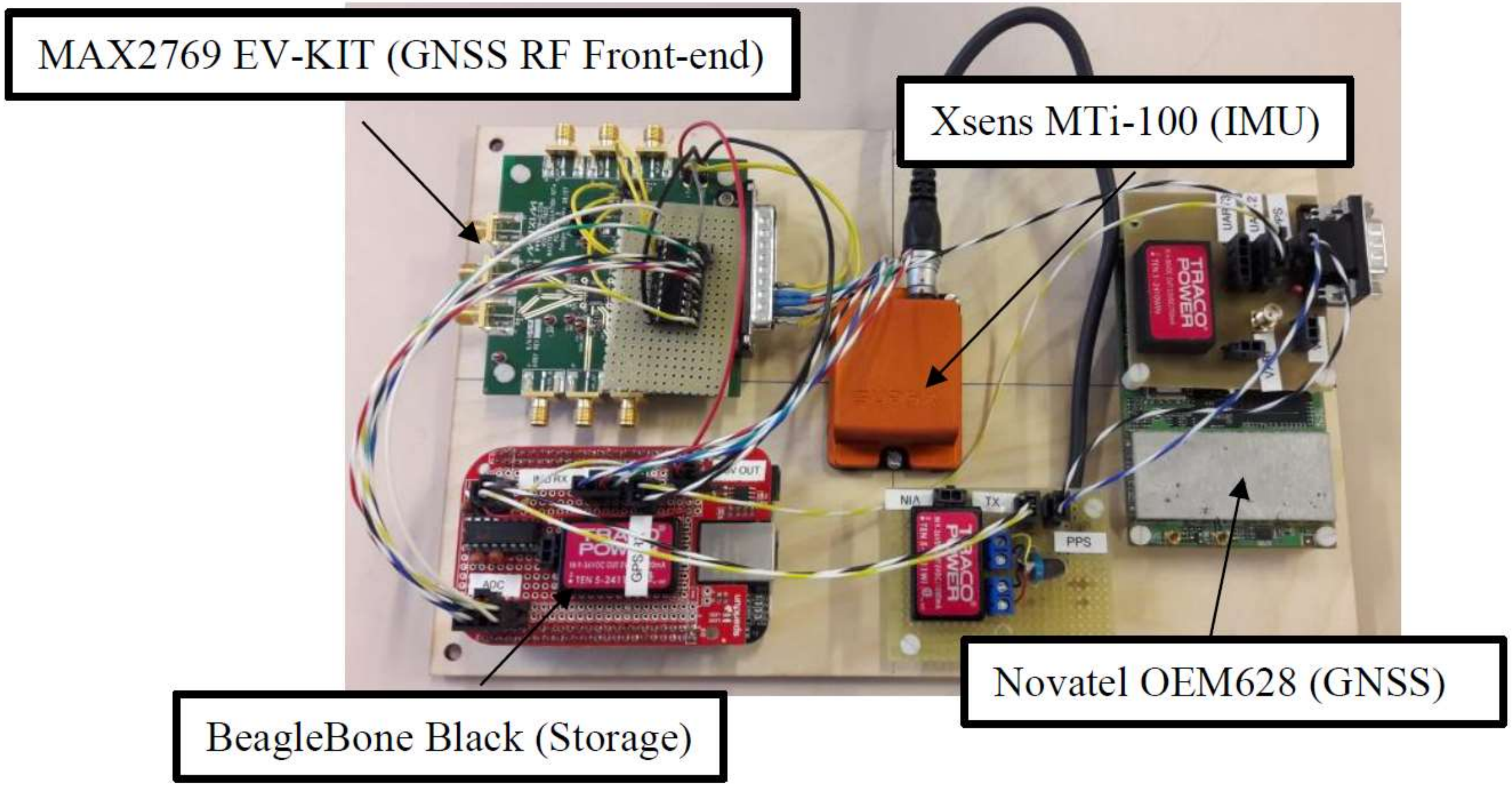
-The term ”ultra-tight” implies, that low-level access to tracking loops within GNSS receiver is required **(GNSS software receiver)**

-Specialized hardware required for capturing GNSS IF data

Commercial solutions do exist, but was too heavy to be used with small UAVs, hence **own solution** was developed

Olesen et. al (2014-2017)

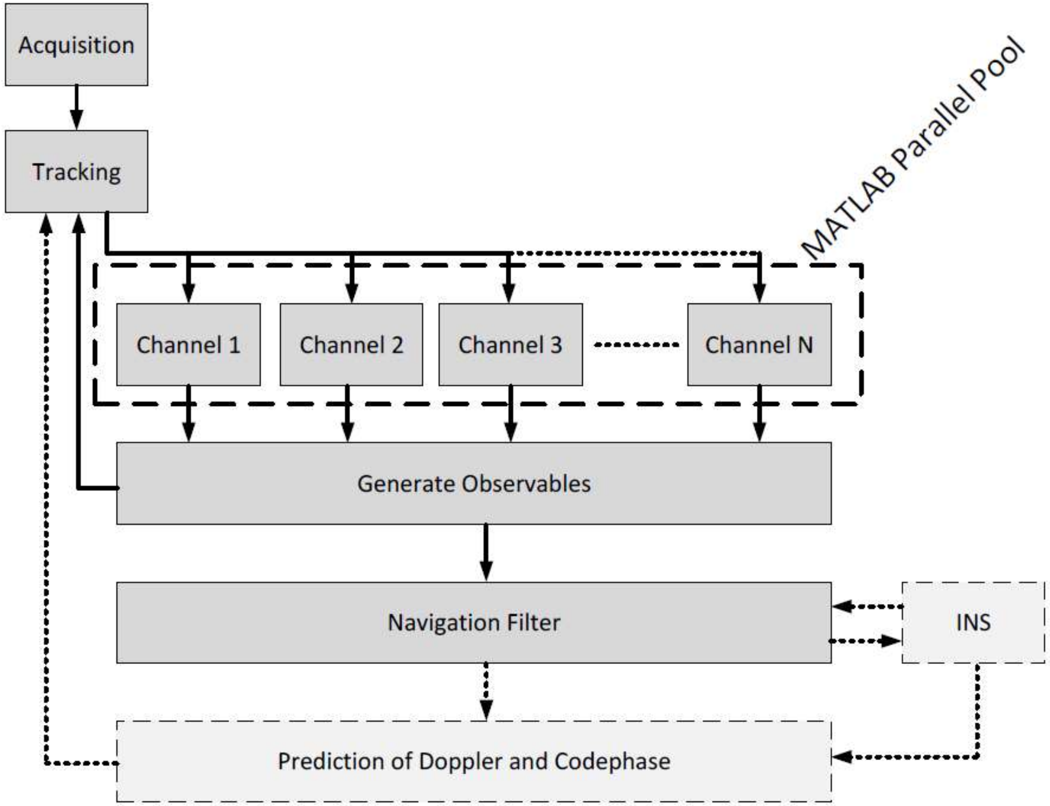
Data Collection System



Weight: 450 g

Area: 27 x 17 [cm]

Data Processing



Implemented in Matlab

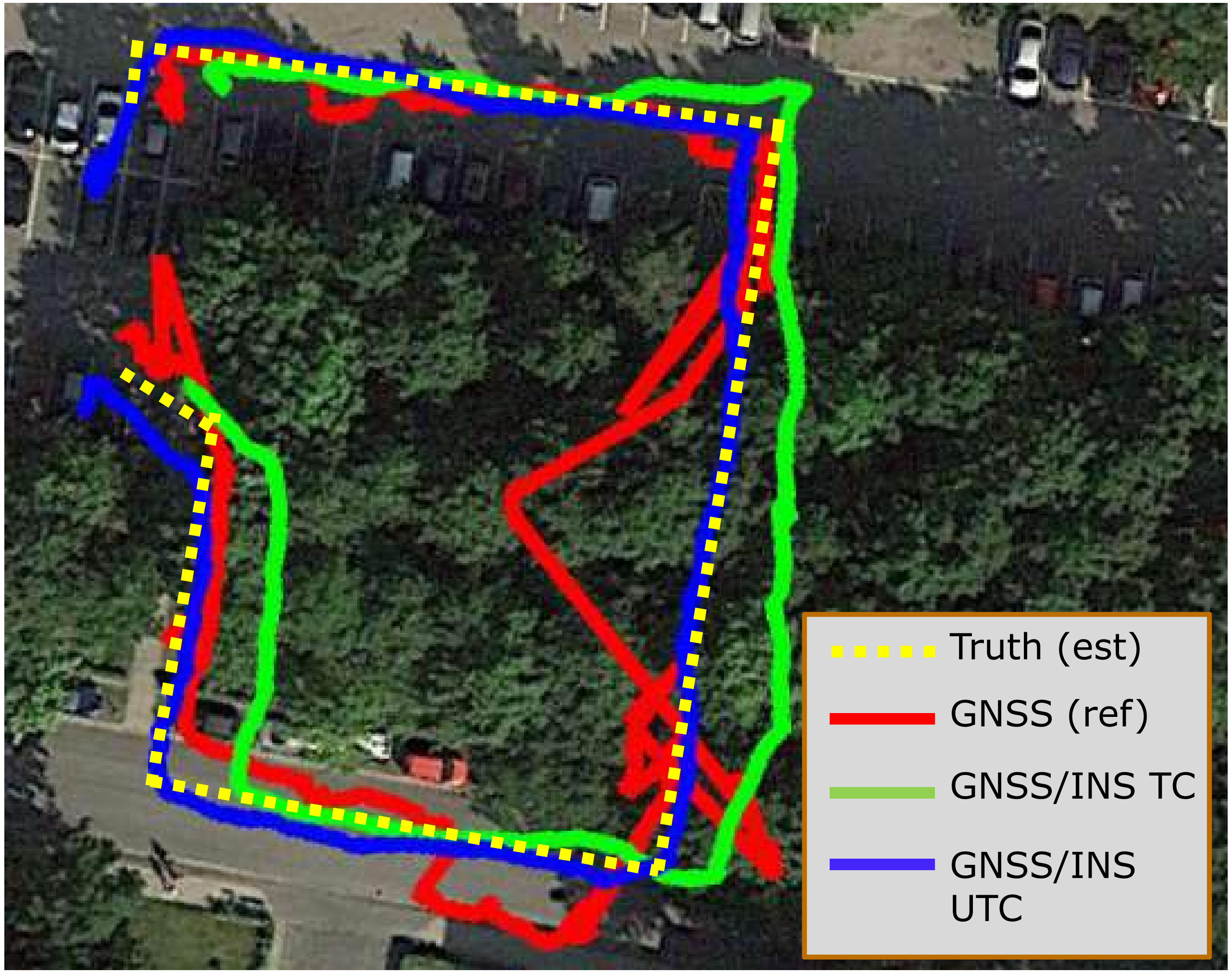
- Acqusition based on Parallel Code Phase Search (using fft)
- DRC implemented with C++ mex files
- Parallel Toolbox® for tracking
- Scalar Receiver process each channel independently
- Ultra-Tight Receiver uses INS + GNSS navigation solution to predict NCOs for code- and carrier generation for next epoch

Experimental Results

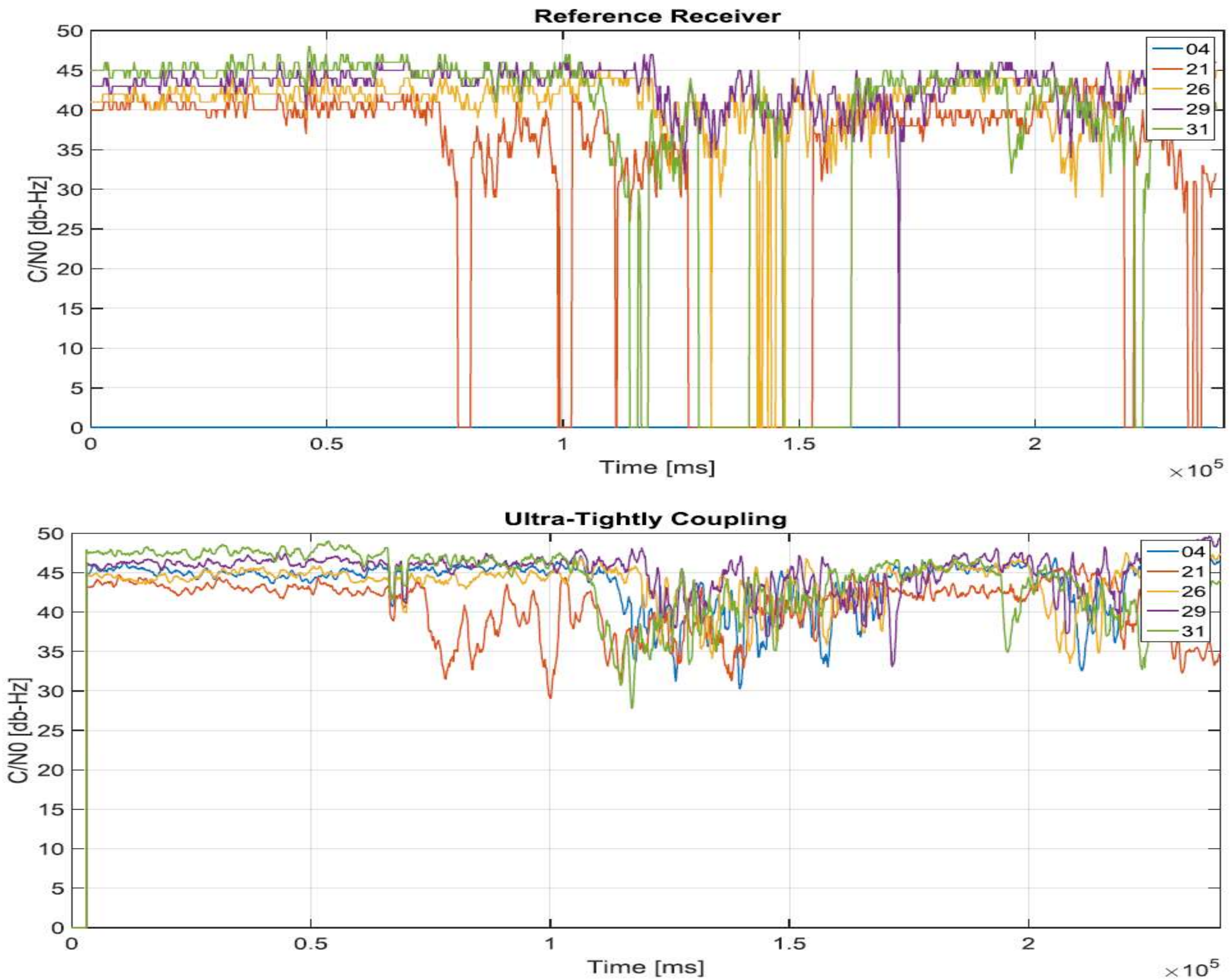
- Developed system was evaluated in three conditions
- Static test (lab-test)
- 4-wheeled trolley
- <u>**UAV**</u>
- Comparison of tightly-coupled solution with ultra-tightly coupled solution

UAV results

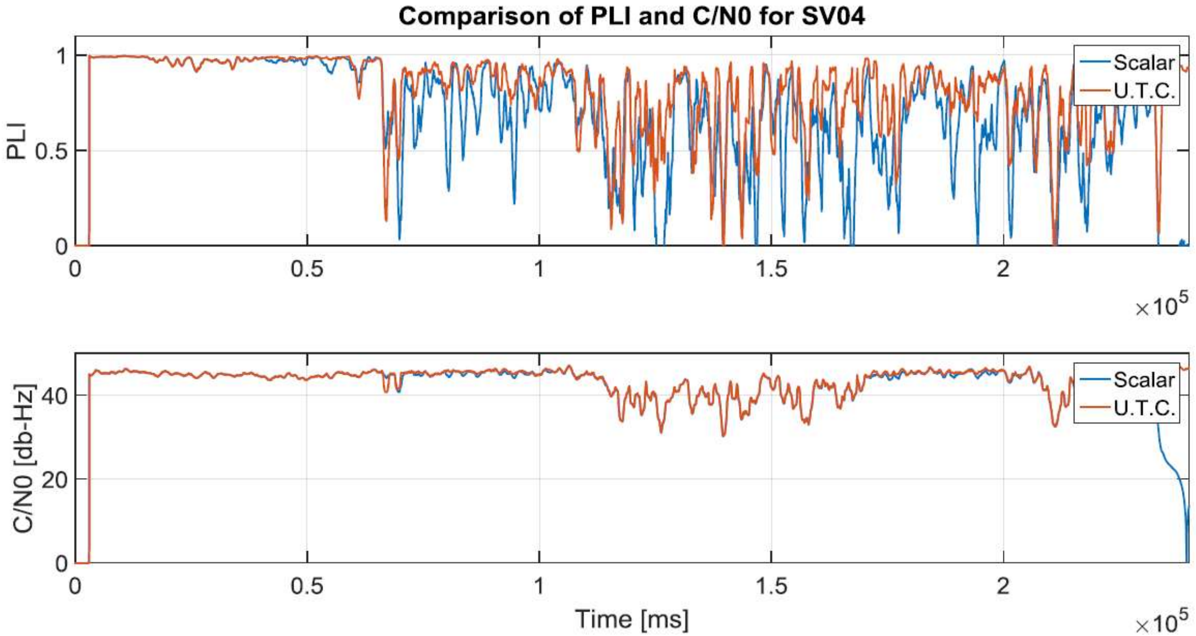
UAV mission



Results (C/N0 comparison)



Results (Phase-Lock Indicator)



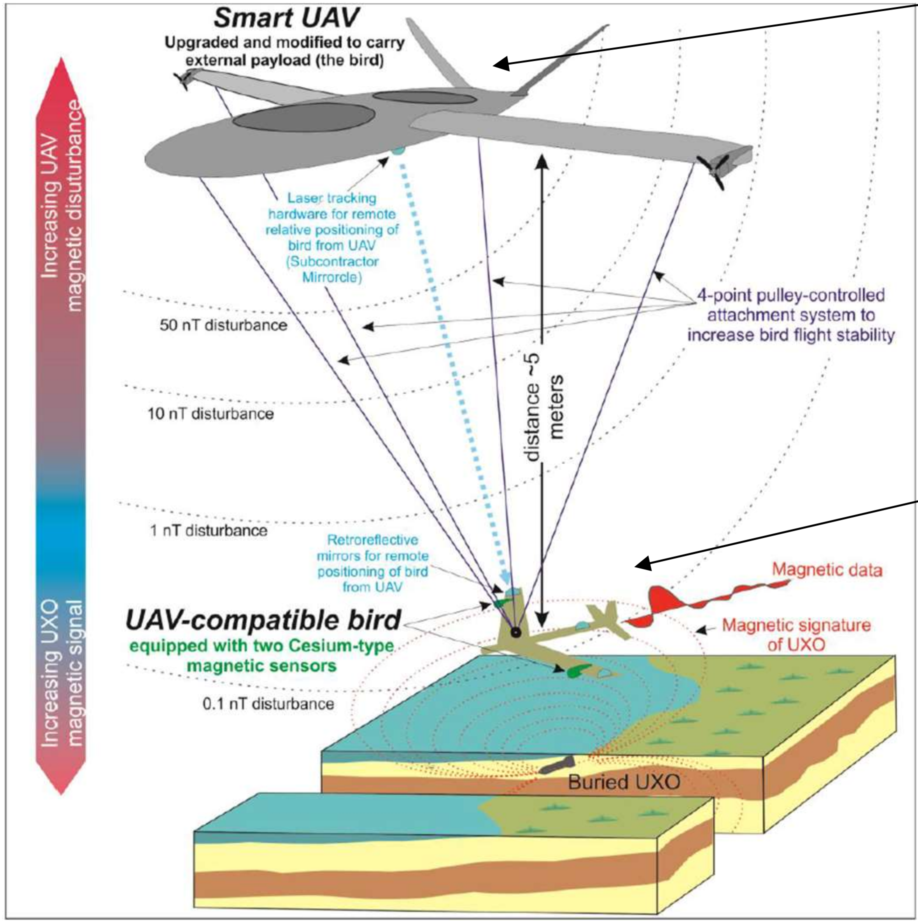
Mean PLI

SV	Scalar	U.T.C.
04	0.669	0.814
21	0.634	0.757
26	0.660	0.821
29	0.488	0.836
31	0.248	0.778

Future Perspectives

- Support for Gallileo E1 OS, GLONASS L1 C/A …
- Analysis of improvements in differential carrier phase positioning in GNSS degraded environments
- Addition of Visual Odometry system to navigation solution
- Real-time capability / Direct integration to UAV flight controller

Relative pose-estimation of magnetometer bird



Positioning of UAV

Tightly-coupled GNSS/INS (Novatel SPAN)

Sensor bird position and attitude is determined relative to UAV with downward camera and fiducial markers

PhD project of Xiao Hu

Objectives

- Develop positioning system using optical camera to estimate relative pose of sensor bird

- Makes uses of artifical circular fiducial markers on sensor bird
  - Detection of markers and ellipsoidal fitting
  - Perspective-N-Points algorithm

- Initial tests has been performed using optical motion capture system as reference and static markers indoors

- Planned test to evaluate dynamic performance of system and compare results with TC GNSS/INS directly on sensor bird

Flight test (without reference)

Circular Experiments flight tests

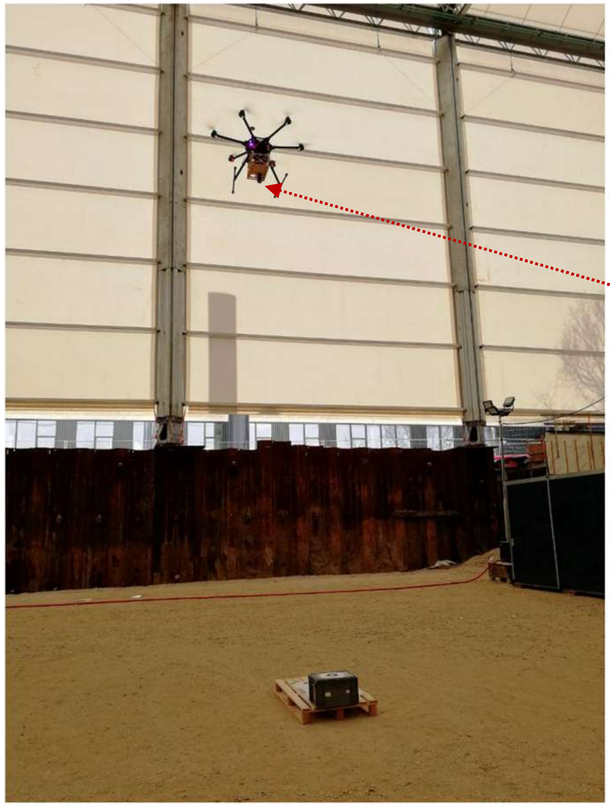


Figure 4.15: Experiment Setup.

Flight tests:
2 tests with MatrixVision camera with customized payload;

4 tests with GoPro:
2.7K V.S. 1080P

Ground Truth with preprinted paper.

Circular Experiments GoPro Summary

Table 4.3: Results from the benchmark.

Experiment	Mean 3D eror (m)	Std Deviation	Outlier Filtering
2.7K 30FPS no Depth	0.0326	0.0558	none
2.7K 60FPS no Depth	0.0538	0.1001	none
1440p 30FPS no Depth	0.0434	0.0521	1σ
1440p 30FPS Depth	0.0400	0.0410	3σ
2.7K 30FPS Depth	0.0543	0.0818	3σ
1440p 30FPS Depth	0.0466	0.0546	3σ

Detailed reports:

https://owncloud.spacecenter.dk/owncloud/index.php/s/mw234OfxPcuz2PU

Circular Experiments

Static test: benchmarked with Opti-track system

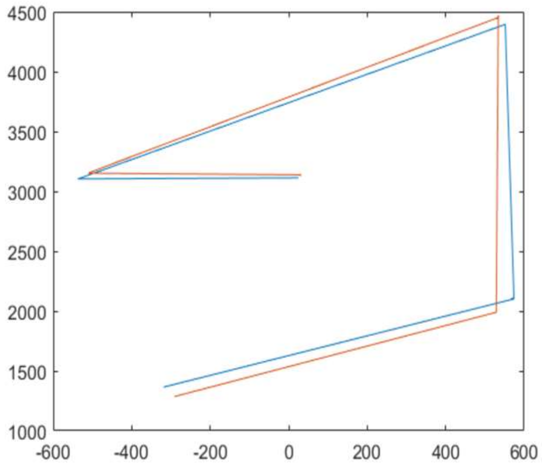
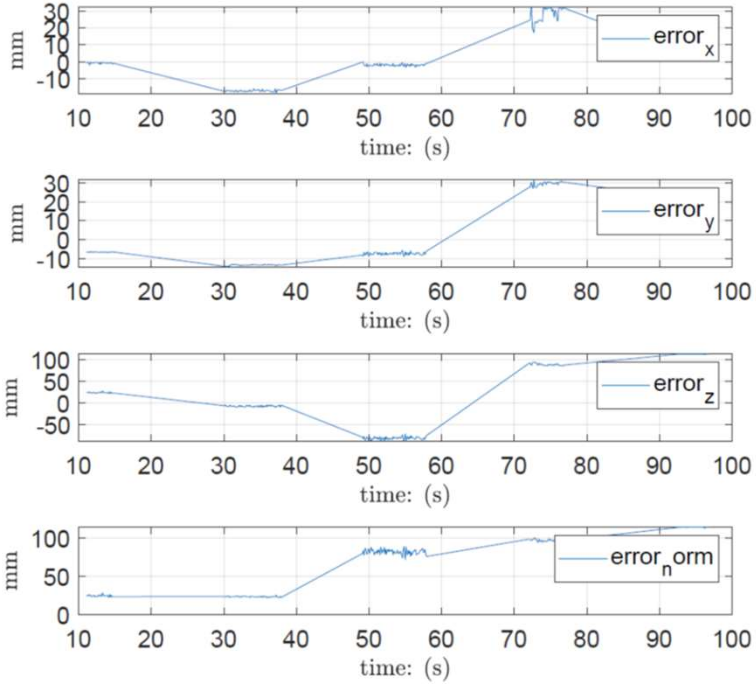


Figure 4.13: Ground Truth and Estimated Trajectories of the X and Y.



Next steps…

- Evaluate and benchmark system against a GNSS/INS system in sensor-bird

- Real-time processing