amsterdam FIG WORKING WEEK 2020
10 – 14 MAY

SMART SURVEYORS FOR LAND AND WATER MANAGEMENT

Arash Jouybari

Department of Computer and Geospatial Sciences, University of Gävle, Gävle, Sweden

Assessment of different GNSS and IMU observation weights on photogrammetry aerial triangulation

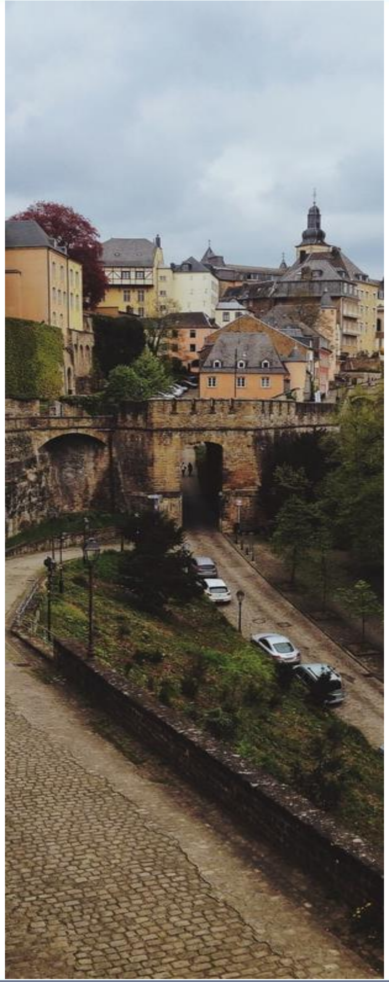
Assessment of different GNSS and IMU observation weights on photogrammetry aerial triangulation

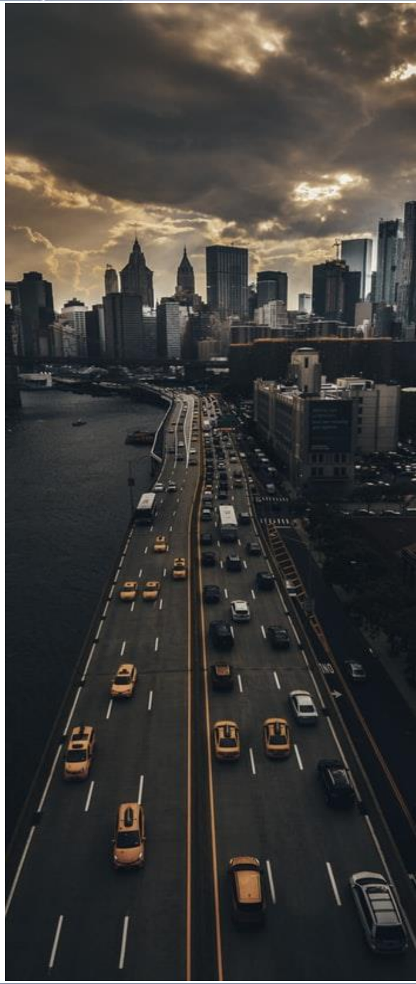
Arash JOUYBARI, Mohammad BAGHERBANDI, Faramarz NILFOUROUSHAN

Introduction

http://www.imo.org/en/MediaCentre/PressBriefings/Pages/41-SDGS.aspx

Geospatial and Temporal data



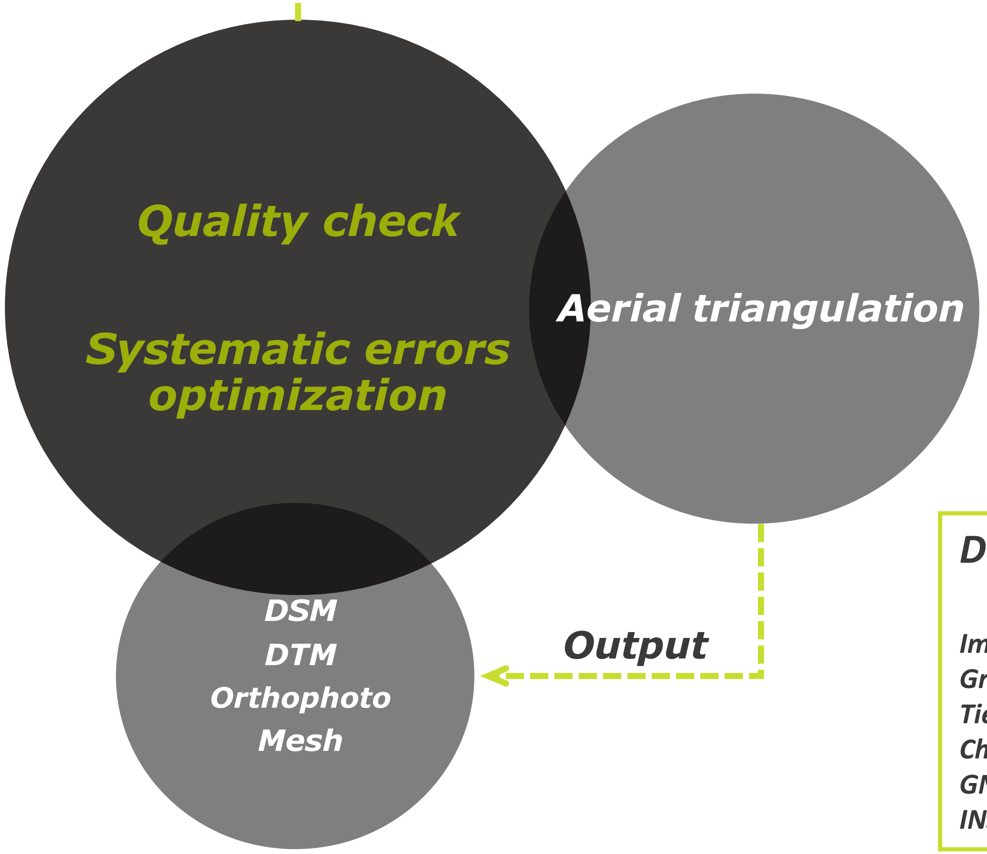


Study Purpose

Applications:

- *City Planning*
- *3D modeling*
- *Disaster Management*
- *Deforestation*
- *…*

High Quality Data

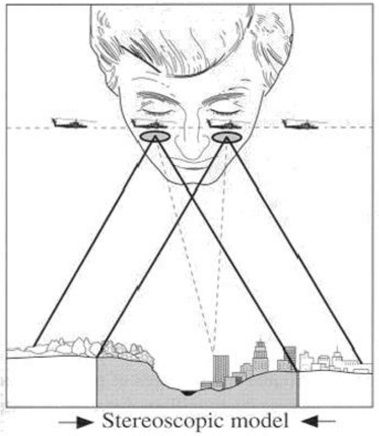


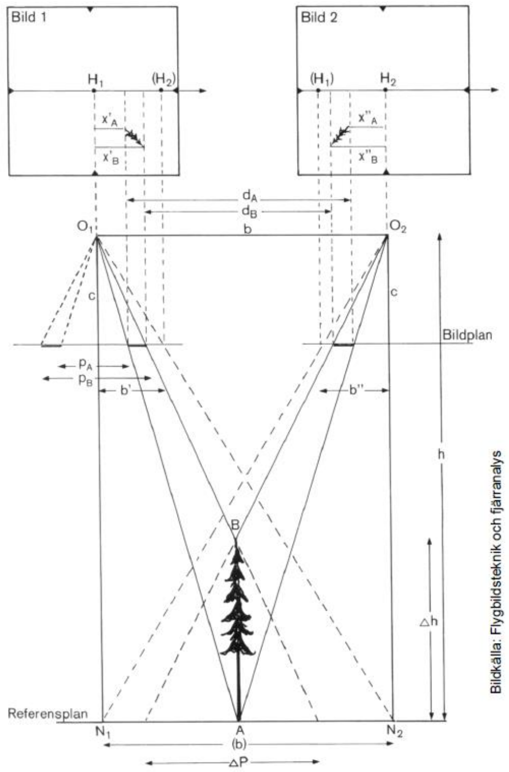
Data:

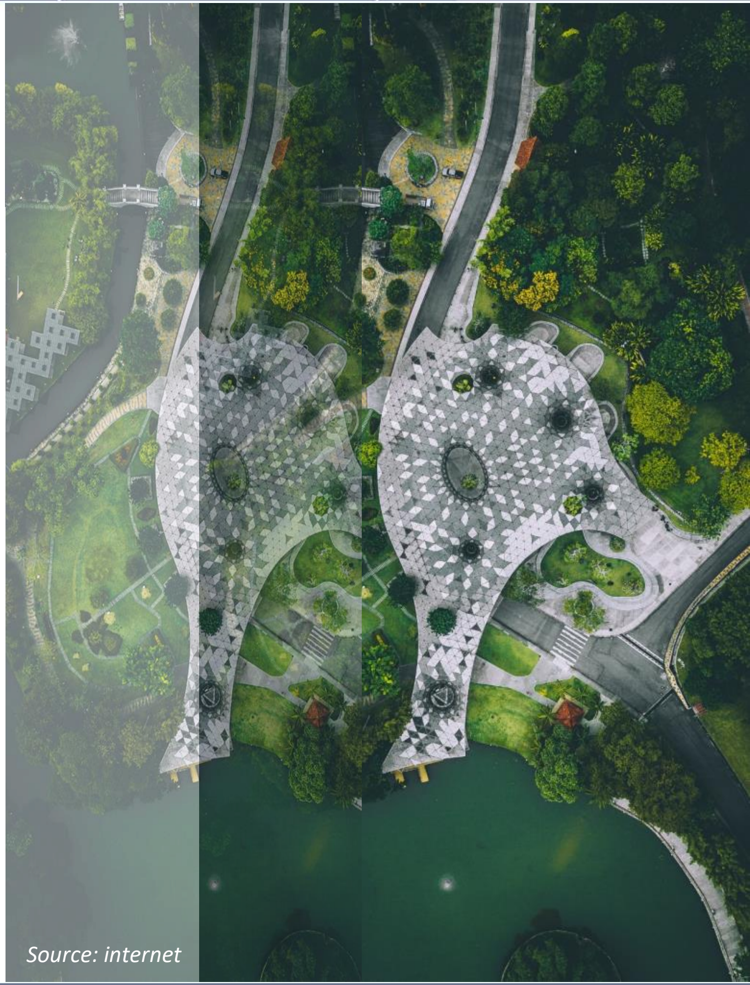
Image data
Ground Control Points
Tie Points
Check Points
GNSS data
INS data

Introduction [photogrammetry]

Photo = Light
Gram = Recording
Metry = Measurement





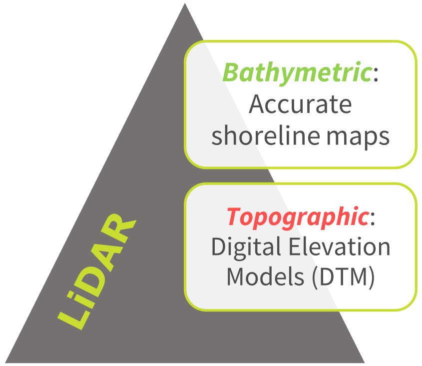


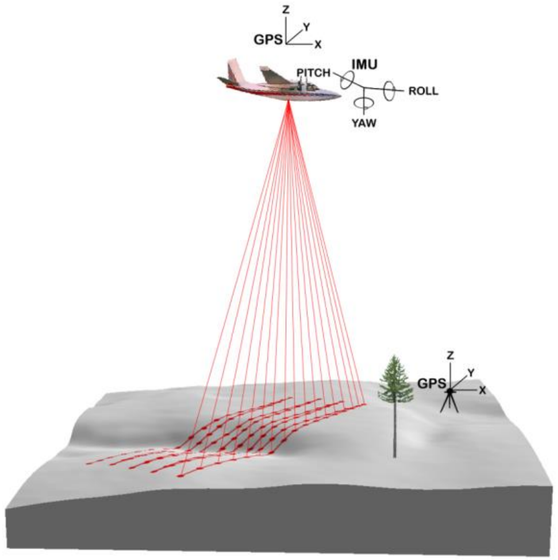
Introduction [LiDAR]

LiDAR stands for Light Detection and Ranging, commonly known as ***Laser Radar***

Aerial LiDAR System Components:

- Aircraft
- Scanning laser emitter-receiver unit
- Differentially-corrected GPS
- Inertial measurement unit (IMU)
- Computer





Source: internet

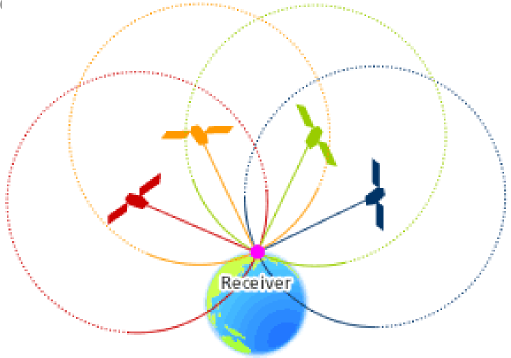
Introduction [GNSS]

Global Navigation Satellite System

- Europe's **Galileo**
- The USA's NAVSTAR Global Positioning System (**GPS**)
- Russia's Global'naya Navigatsionnaya Sputnikovaya Sistema (**GLONASS**)
- China's **BeiDou** Navigation Satellite System

GNSS/GPS applications includ

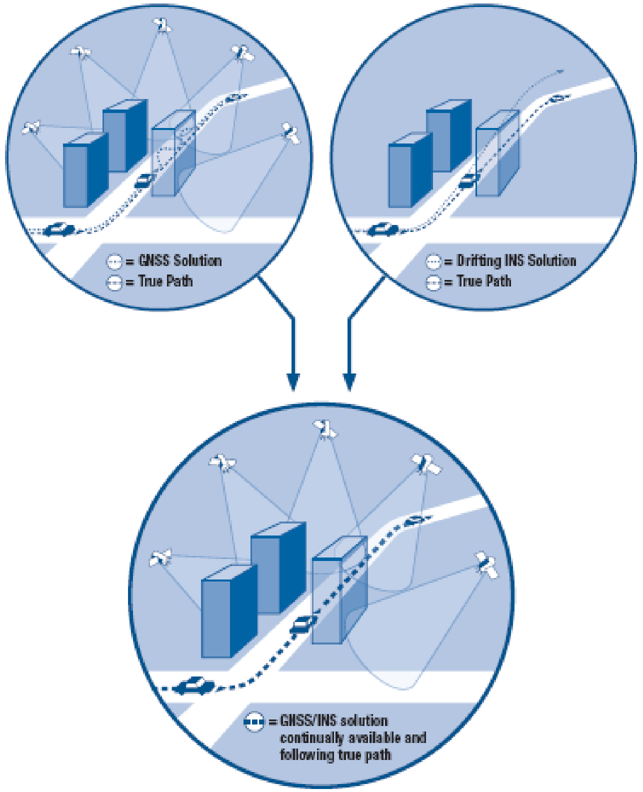
- Tracking/Mapping Devices
- Industrial Machinery
- Sea vessels
- Air Navigation
- Automobiles



Source: internet

Introduction [GNSS/INS integration]

Combination of GNSS and INS will give continuous position, time and velocity information, even in difficult environments where there is limited GPS satellites in view



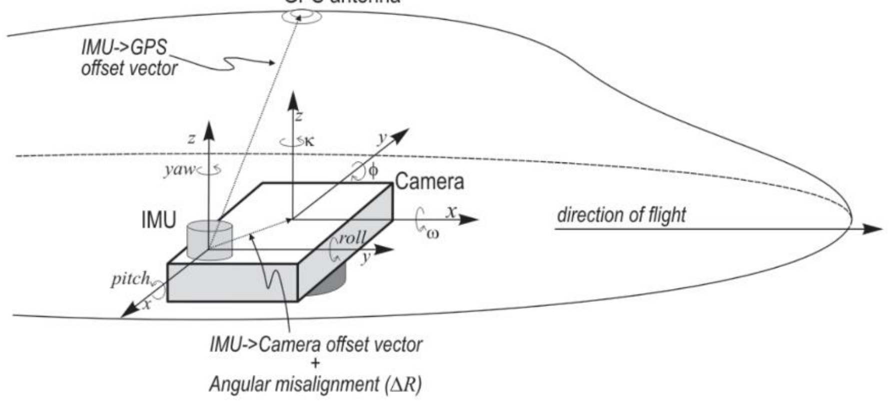
Source: internet

Introduction [Aerial Triangulation Vs. Direct Georeferencing]

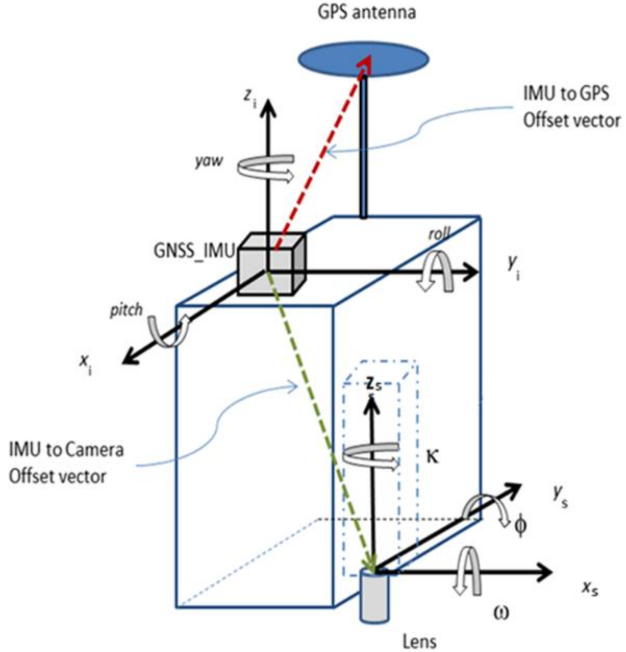
Calibrate some parameters:

- lever arm,
- boresight misalignment,
- camera interior orientation,
- some other sensor noise and errors

GNSS shift and drift errors



https://www.novatel.com/assets/Documents/Papers/D11716.pdf



https://doi.org/10.1117/1.JRS.10.014002

Source: internet

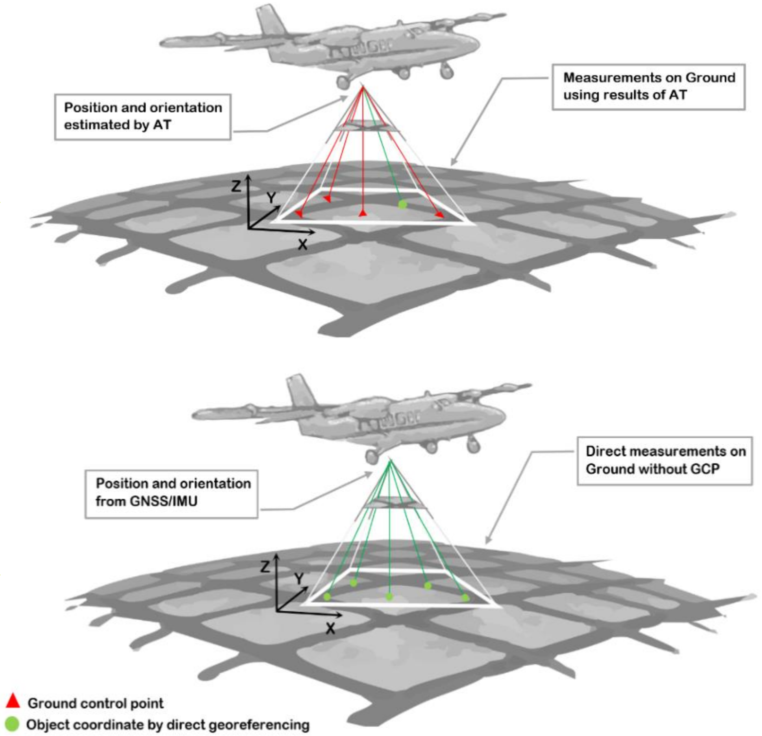
Introduction [Aerial Triangulation Vs. Direct Georeferencing]

Aerial Triangulation

More accurate

Faster

Direct Georefrencing



Source: internet

Study Background

Schmitz and Wübbena 2001
- the rigorous **GPS modeling** in the combined GPS/block adjustment
- compared it with shift and drift approach
- Better accuracy-IMU beside GPS-supported AT

Mostafa and Hutton 2001
- POS/Av 510
- DG in conjunction with standard stereo model + a single photo
- accuracy of DG meets the theoretical admissible accuracy for map production

Kruck 2002
- Applanix **V.s.** IGI in two different photo scale considering GNSS shift and drift effect
- **Applanix** had lower RMS (better accuracy)

Shift and drift effect

Sensors Fusion

Direct Georeferencing

Sensors' brand

Cramer 2006
- Imaging sensor + Countinuous GPS/INS data
- Kalman filter (strip-wise integration approach)
- Accuracy Horizontal = 10-20 cm
  Vertical = 20-30 cm

Blázquez and Colomina 2012
- Introduced functional models using relative aerial control instead of absolute position
- Removed completely GNSS shift and drift error besides IMU-to-camera boresight misalignment angle

Kersten and Haering 1998; Heipke 1999
- Tie points extraction in lake, forest and mountain area is hard.
- GNSS/IMU data collection during project

Mostafa et al. 2001
- independent photogrammetrically derived reference trajectory **V.s.** US National Geodetic Survey (NGS) Continuously Operating Reference Station (**CORS**)

Purpose and Data

Purpose:

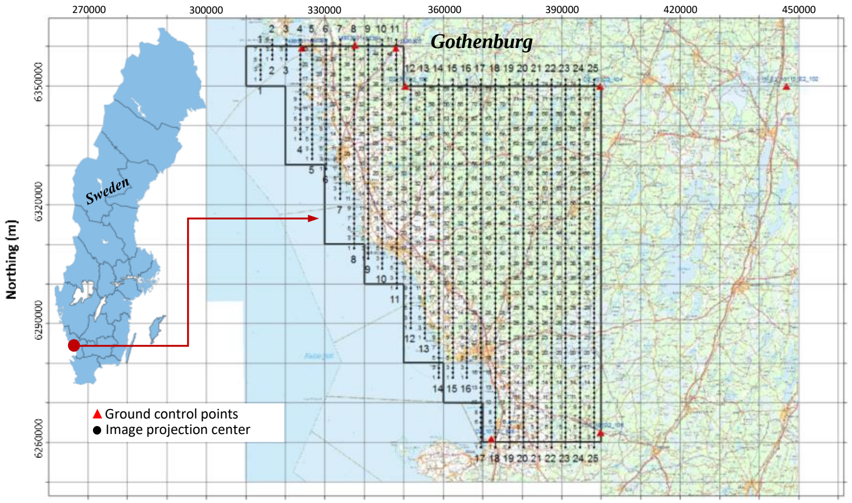
- To finding best GNSS/IMU weight in aerial triangulation process

Study area and data:

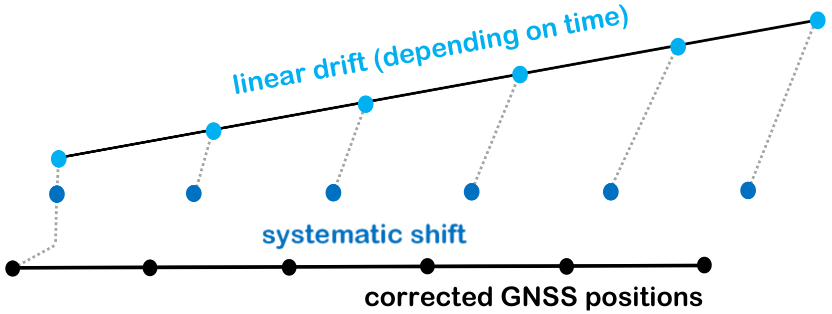
- Gothenburg, Sweden – July, 08, 2019
- Lantmäteriet, the Swedish mapping, cadastral and land registration authority
- 0.25 m ground sample distance (GSD)
- The test field size is approximately 75 × 90 km²
- 25 strips, 1198 images
- 60% forward overlap 25% lateral overlap

- Applanix POS AV 510 – GNSS/IMU Equipment
- Ultracam Eagle digital camera with an 80 mm lens

Test area with scale: 1:503000. Coordinates are in SWEREF99 TM reference system.



Method



GNSS shift and drift errors

- GNSS antenna-eccentricity
- GNSS reference stations are far away from the project area
- Incorrect On The Fly (OTF) integer ambiguities in GNSS kinematic observations

$$f_x = \left(x'_0 + d_{x'_0}\right) - \left(\mathrm{f} + d_{\mathrm{f}}\right) \times \left[\frac{r_{11}\left(X - X_0\right) + r_{21}\left(Y - Y_0\right) + r_{31}\left(Z - Z_0\right)}{r_{13}\left(X - X_0\right) + r_{23}\left(Y - Y_0\right) + r_{33}\left(Z - Z_0\right)}\right] + \delta_{shift} + \left(t - t_0\right)\delta_{drift} \quad ,$$

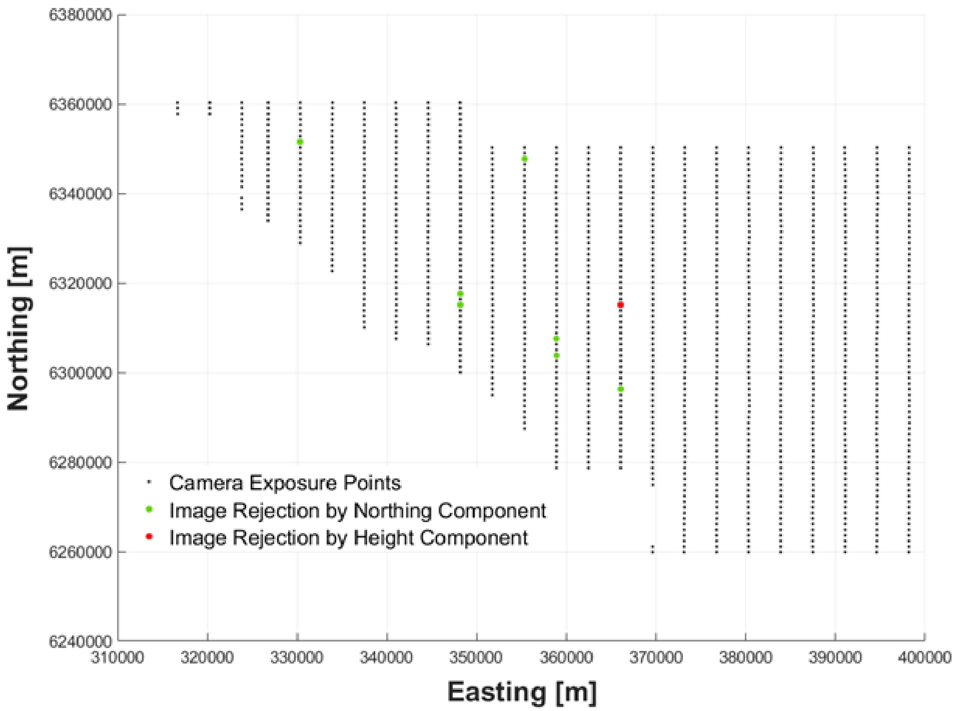
$$f_y = \left(y'_0 + d_{y'_0}\right) - \left(\mathrm{f} + d_{\mathrm{f}}\right) \times \left[\frac{r_{12}\left(X - X_0\right) + r_{22}\left(Y - Y_0\right) + r_{32}\left(Z - Z_0\right)}{r_{13}\left(X - X_0\right) + r_{23}\left(Y - Y_0\right) + r_{33}\left(Z - Z_0\right)}\right] + \delta_{shift} + \left(t - t_0\right)\delta_{drift} \; ,$$

Result

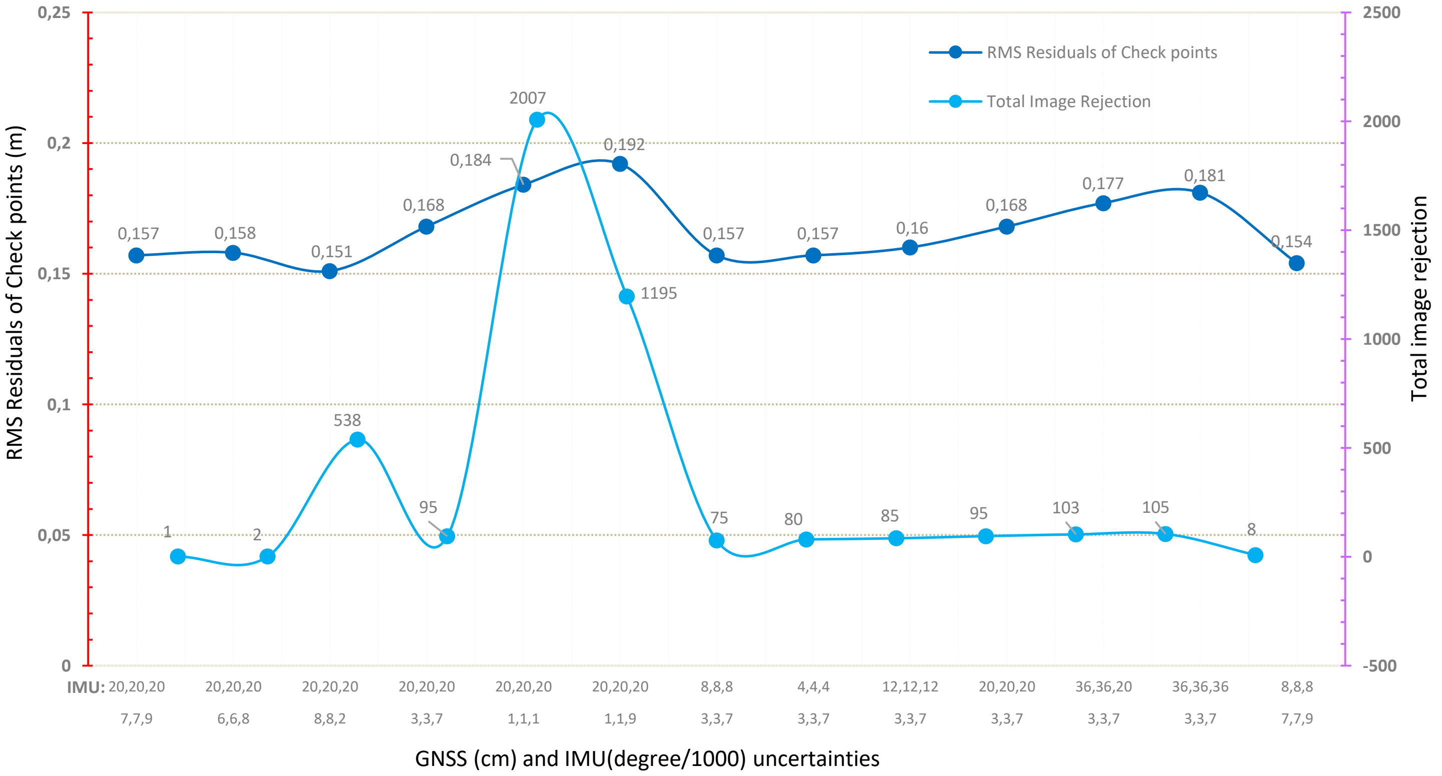
Observation uncertainty		Numbers of image rejection							RMS Residual check Points (m)
GNSS (meter) $u(E)$, $u(N)$, $u(H)$	IMU (°) $u(\omega)$, $u(\varphi)$, $u(\kappa)$	*E*	*N*	*H*	ω	φ	κ	*Total*	
0.2, 0.2, 0.2	*0.007, 0.007, 0.009*	0	1	0	0	0	0	1	0.157
	0.006, 0.006, 0.008	0	1	0	1	0	0	2	0.158
	0.008, 0.008, 0.002	0	1	0	0	0	537	538	0.151
	0.003, 0.003, 0.007	0	0	0	92	0	3	95	0.168 *
	0.001, 0.001, 0.001	36	33	0	1188	2	748	2007	0.184
	0.001, 0.001, 0.009	1	0	0	1193	1	0	1195	0.192
0.08, 0.08, 0.08	*0.003, 0.003, 0.007*	1	6	0	65	0	3	75	0.157
0.04, 0.04, 0.04		0	3	14	60	0	3	80	0.157
0.12, 0.12, 0.12		1	5	0	76	0	3	85	0.16
0.2, 0.2, 0.2		0	0	0	92	0	3	95	0.168 *
0.36, 0.36,0.2		0	0	0	100	0	3	103	0.177
0.36, 0.36, 0.36		0	0	0	102	0	3	105	0.181
0.08, 0.08, 0.08	*0.007, 0.007, 0.009*	0	7	1	0	0	0	8	0.154

The number of image rejection and checkpoints RMS of some best case, worst case and Lantmäteriet default (*) for observations uncertainties.

T-test evaluation of Images with higher errors



Result


RMS Residuals of Check points
Total Image Rejection
RMS Residuals of Check points (m)
Total image rejection
0,25
0,2
0,15
0,1
0,05
0
2500
2000
1500
1000
500
0
-500
0,157
0,158
0,151
0,168
0,184
0,192
0,157
0,157
0,16
0,168
0,177
0,181
0,154
1
2
538
95
2007
1195
75
80
85
95
103
105
8
IMU: 20,20,20
7,7,9
20,20,20
6,6,8
20,20,20
8,8,2
20,20,20
3,3,7
20,20,20
1,1,1
20,20,20
1,1,9
8,8,8
3,3,7
4,4,4
3,3,7
12,12,12
3,3,7
20,20,20
3,3,7
36,36,20
3,3,7
36,36,36
3,3,7
8,8,8
7,7,9
GNSS (cm) and IMU(degree/1000) uncertainties

Thank you for your attention