Best way to fly DatuBIM

Research Investigation

Datumate

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Datumate
Build with intelligence
Unleash the power of AI to boost
construction project efficiency

Objective

Datumate is a construction technology (Contech) company offers a SaaS data analytics photogrammetry 4D BIM platform based on AI engine for stakeholders across the construction project lifecycle.

- Beside laser scanning data, the main mapping input for **DatuBIM** is the drone images.

- This investigation research work tries to find the best way of taking images from drones.

Research Experimentation

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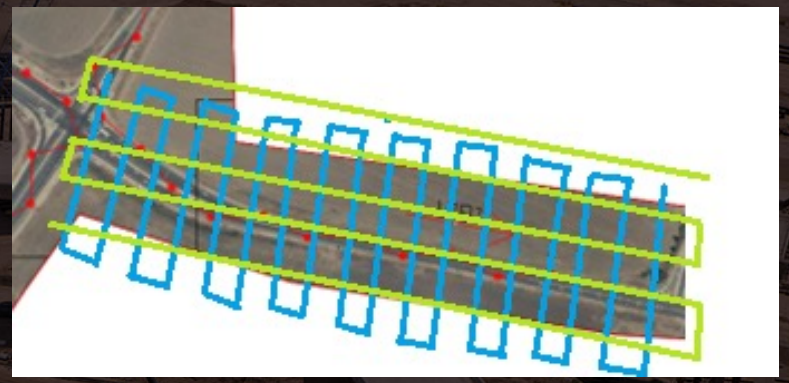
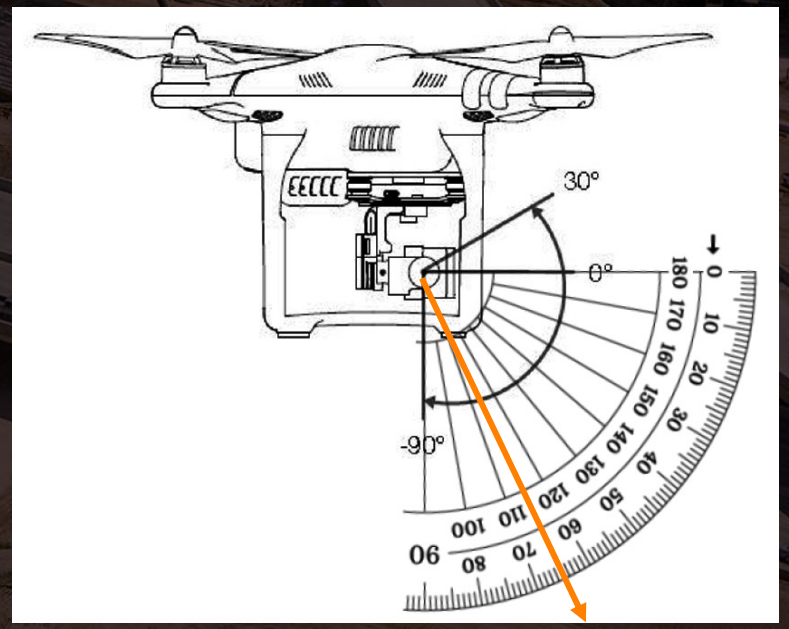
Experimentation objectives

- What is the best accuracy user can derive from DatuBIM ? What he should do for it?
- How do the flight parameters affect the mapping accuracy?
  - Camera
  - Flight elevation
  - Camera angle from the horizon
  - Double\single grid
- How do the GCPs number, their density and scattering affect the mapping accuracy?
- Proving the assumption says:
  - The accuracy values of the GCPs make using higher resolution images than it values, unnecessary
- Recommendations

The research site and different parameters:

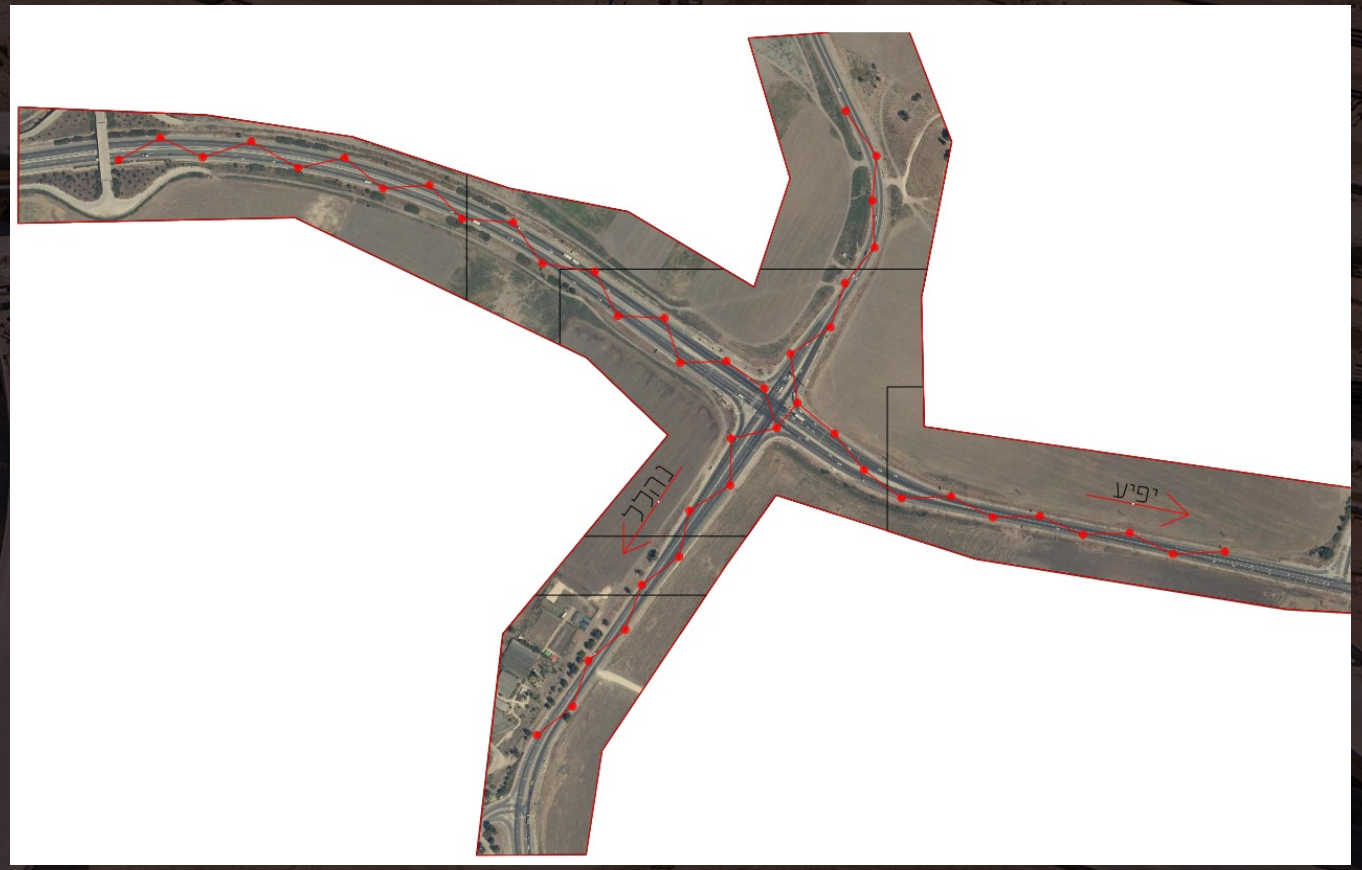
- **The site:**
  - Nahlal junction in Israel, ~ 2.5 km open roads.
  - Asphalt area ~ 340,000 sqm
- **The flight parameters:**
  - Phantom 4 Enterprise RTK (1" CMOS; Effective pixels: 20 MPX)
  - Flight trajectory:
    - One flight perpendicular to the road (**P1R**) center line in **blue**,
    - Second flight is a double flight adding the **green** flight trajectory in parallel to the road (**P2R**) center line.
  - The angle of the camera direction from the horizon:
    - One flight the Angle from horizon (AngH) is 90
    - Second flight AngH ~60-65 degree
  - Flight elevation:
    - One flight 40 m (GSD ~ 1.1 cm\px)
    - Second flight 60 m (GSD ~ 1.65 cm\px)
  - Overlaps : 80% (flight direction), 70% (side direction)





The research site and different parameters:

- **Ground Control Points (GCPs):**
  - 40 GCPs
  - Measured in sessions of RTK GNSS method.
  - Each session duration > 3 min
  - 60 min. diff between each session
  - The above mentioned method enable detecting bad measurements and enables accuracy estimation using the deviations values between each session results.
  - Distances between GCPS ~ 50-75 m.
  - Scattered in Zigzag as it is described in **red** lines in the picture.



Methodology for checking the photogrammetric model accuracies:

- **Checker points:**
  - 60 checker points in addition to the 40 GCPS
  - Measured in sessions of RTK GNSS method.
  - Each session duration > 3 min
  - 60 min. diff between each session
- **6 different flights were done:**
  1. Flight elevation ~ 40 m, **P2R**, Camera Tilt ~ AngH = 90 deg.
  2. Flight elevation ~ 60 m, **P2R**, Camera Tilt ~ AngH = 90 deg.
  3. Flight elevation ~ 40 m, **P2R**, Camera Tilt ~ AngH = 60-65 deg (diagonal).
  4. Flight elevation ~ 60 m, **P2R**, Camera Tilt ~ AngH = 60-65 deg (diagonal).
  5. Flight elevation ~ 40 m, **P1R** + **P2R**, Camera Tilt ~ AngH = 60-65 deg .
  6. Flight elevation ~ 60 m, **P1R** + **P2R**, Camera Tilt ~ AngH = 60-65 deg.
- **3 different variations of GCPs participating in the photogrammetric model solution:**
  1. Using each 75 m GCP, double check the 60 checker points.
  2. Using each 150 m GCP, double check the 60 checker points.
  3. Using each 300 m GCP, double check the 60 checker points.
- Using well-defined natural checker points such loke a corner of white color signs on asphalt.

Investigations results

DatuBIM

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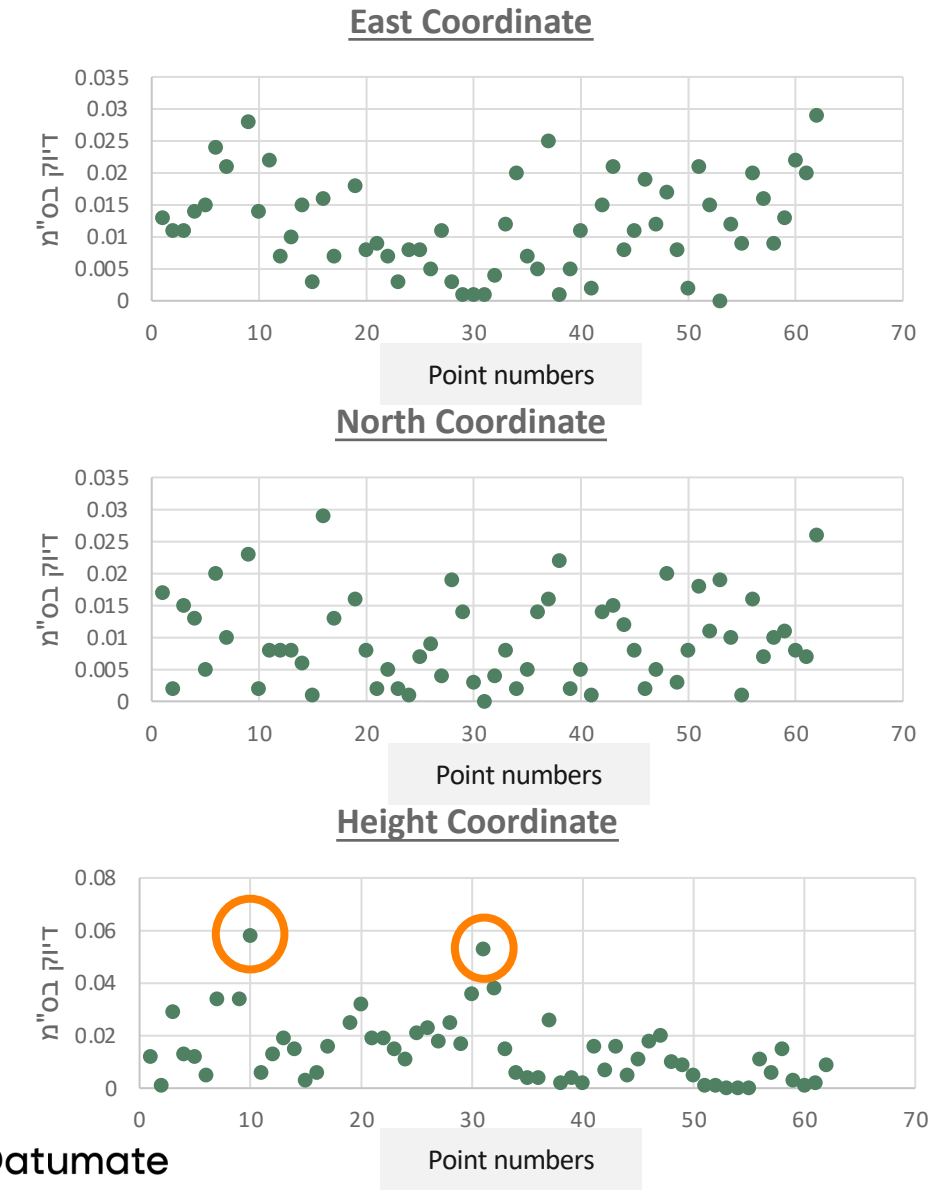
Distribution of GCP and Checker coordinates deviations in 3D



	Session-1			Session-2			Deviations		
1	219677.566	734045.941	105.141	219677.579	734045.924	105.129	0.013	-0.017	0.012
2	219694.136	734034.283	105.44	219694.125	734034.281	105.439	-0.011	-0.002	0.001
3	219708.876	734026.752	105.769	219708.887	734026.737	105.74	0.011	-0.015	0.029
4	219738.283	734007.246	106.437	219738.297	734007.233	106.45	0.014	-0.013	0.013
5	219757.146	733994.181	106.82	219757.161	733994.176	106.832	0.015	-0.005	0.012
6	219737.113	733978.565	106.098	219737.137	733978.545	106.103	0.024	-0.02	0.005
7	219718.352	733925.672	104.519	219718.331	733925.662	104.485	-0.021	-0.01	0.034
9	219587.052	733726.597	100.486	219587.08	733726.574	100.52	0.028	-0.023	0.034
10	219568.461	733702.723	100.004	219568.447	733702.721	99.936	-0.014	-0.002	0.068
11	219551.866	733675.424	99.694	219551.888	733675.432	99.7	0.022	0.008	0.006
12	219531.109	733653.832	99.526	219531.102	733653.824	99.539	-0.007	-0.008	0.013
13	219613.892	733764.363	101.348	219613.902	733764.371	101.329	0.01	0.008	0.019
14	219663.47	733818.252	102.49	219663.455	733818.246	102.475	-0.015	-0.006	0.015
15	219686.665	733849.284	103.034	219686.668	733849.285	103.037	0.003	0.001	0.003
16	219726.113	733898.437	104.04	219726.129	733898.408	104.034	0.016	-0.029	0.006
17	219770.496	733954.831	106.811	219770.489	733954.844	106.795	-0.007	0.013	0.016
19	219856.989	733911.05	109.953	219857.007	733911.066	109.928	0.018	0.016	0.025
20	219889.235	733899.939	110.537	219889.243	733899.947	110.505	0.008	0.008	0.032
21	220309.621	733820.609	119.872	220309.63	733820.607	119.853	0.009	-0.002	0.019
22	220275.282	733823.55	119.232	220275.275	733823.545	119.213	-0.007	-0.005	0.019
23	220239.728	733833.666	118.581	220239.725	733833.664	118.566	-0.003	-0.002	0.015
24	220204.572	733840.165	117.746	220204.564	733840.164	117.735	-0.008	-0.001	0.011
25	220163.567	733847.735	116.69	220163.559	733847.728	116.669	-0.008	-0.007	0.021

- Only two points with deviation ~ 6 cm which did not participate in the work.
- We use the average coordinates of the 2 sessions:
- **Final av. Coordinates STDR of GCPs and Checkers ~ 1.0 cm in 3D in 68% prop. %**

Automatic DatuBIM GCPs accuracies report

GCP Name	Measured (1) [m]			Photo Model Calcs (2) [m]			Residuals (1) - (2) [m]		
Name	East	North	Elevation	East	North	Elevation	DE	DN	DElv.
1	220284.601	733826.612	119.358	220284.606	733826.620	119.365	-0.005	-0.008	-0.007
2	220215.748	733824.880	117.792	220215.730	733824.887	117.797	0.018	-0.007	-0.005
3	220158.242	733849.734	116.515	220158.246	733849.732	116.531	-0.004	0.002	-0.016
4	220105.628	733848.728	114.989	220105.609	733848.725	114.988	0.019	0.003	0.001
5	220052.954	733869.529	113.485	220052.935	733869.529	113.482	0.019	0.000	0.003

⋮

	Residuals (1) - (2) [m]		
	DE	DN	DElv.
Mean	**0.008**	**0.008**	**0.006**
σ - Sigma	**0.005**	**0.006**	**0.004**
RMSE	**0.011**	**0.012**	**0.008**

Values of the bundle adjustment process derived from DatuBIM photogrammetric engine indicates very similar results, comparing the photogrammetric model digitizing results with the average measured of each 2 session of each GCP

Distance measurements comparison for checking DatuBIM ability to produce high accuracy scale mapping

- **The main objective**: comparing between distance measurements on the 3D model using the DatuBIM platform and between the calculated distance derived from the measured coordinates of checker points or GCPs:

$$Dist = \sqrt{(E_2 - E_1)^2 + (N_2 - N_1)^2}$$

- 100 distances were chosen arbitrary.
- **An example is the distance between point # 5 and 8:**
- According to the Israeli regulation the deviations should be better than 5 cm in more than 95% of the statistic test for 1:250 scale of topographic mapping:

	Average Deviation [m]	Standard Deviation [m]
Vertical 60m	0.02	0.021
Diagonal 60m	0.02	0.032
Double-grid 60m	0.01	0.011
Vertical 40m	0.01	0.009
Diagonal 40m	0.01	0.18
Double-grid 40m	0.02	0.023

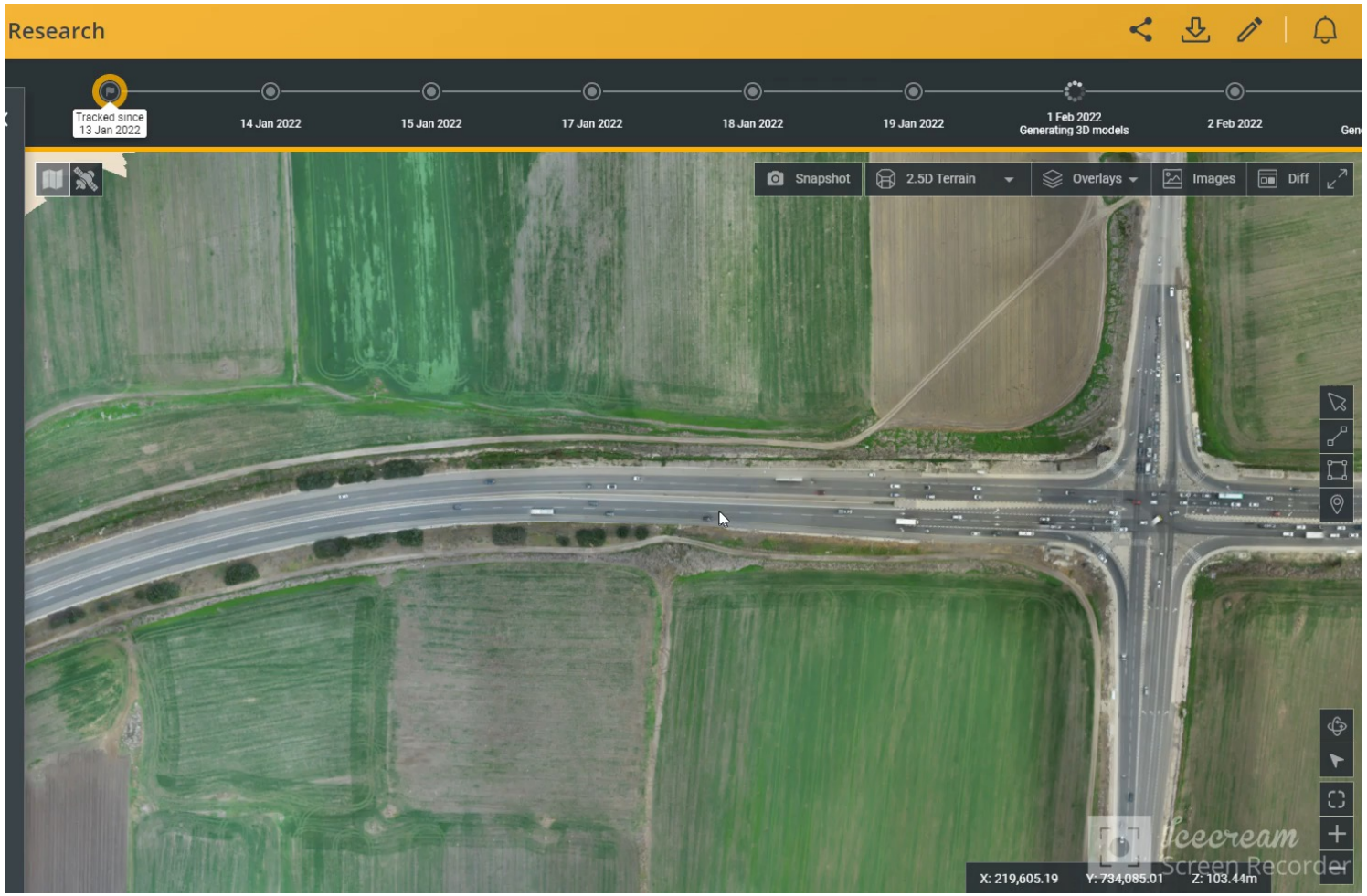
All the 6 flights passed the test

Computing the deviations between each flight checker points DatuBIM coordinates vs. the measured coordinates

- **Example of the coordinates deviations of the first 3 flights**

	Digitized from model - 13.1.2022						Digitized from model - 14.1.2022						Digitized from model - 15.1.2022					
H [m]	E [m]	N [m]	H [m]				E [m]	N [m]	H [m]				E [m]	N [m]	H [m]			
105.135	219677.56	734045.95	105.14	0.01	0.02	0.00	219677.58	734045.96	105.13	0.01	0.03	0.01	219677.57	734045.95	105.13	0.00	0.02	0.01
105.4395	219694.14	734034.32	105.44	0.01	0.04	0.00	219694.13	734034.32	105.43	0.00	0.04	0.01	219694.13	734034.30	105.43	0.00	0.02	0.01
105.7545	219708.90	734026.74	105.77	0.02	0.00	0.02	219708.88	734026.76	105.77	0.00	0.02	0.02	219708.88	734026.76	105.77	0.00	0.02	0.02
106.4435	219738.31	734007.24	106.46	0.02	0.00	0.02	219738.30	734007.24	106.45	0.01	0.00	0.01	219738.31	734007.23	106.44	0.02	0.01	0.00
106.826	219757.16	733994.18	106.84	0.01	0.00	0.01	219757.16	733994.18	106.83	0.01	0.00	0.00	219757.15	733994.18	106.82	0.00	0.00	0.01
106.1005	219737.10	733978.56	106.09	0.02	0.01	0.01	219737.12	733978.56	106.08	0.01	0.01	0.02	219737.12	733978.56	106.08	0.01	0.01	0.02
104.502	219718.33	733925.66	104.51	0.01	0.01	0.01	219718.34	733925.67	104.50	0.00	0.00	0.00	219718.33	733925.68	104.50	0.01	0.01	0.00
103.681	219697.06	733897.32	103.78	0.01	0.01	0.10	219697.06	733897.31	103.77	0.01	0.00	0.09	219697.06	733897.32	103.78	0.01	0.01	0.10
100.503	219587.06	733726.59	100.45	0.01	0.00	0.05	219587.03	733726.60	100.46	0.04	0.01	0.04	219587.04	733726.59	100.46	0.03	0.00	0.04
99.97	219568.44	733702.73	99.96	0.01	0.01	0.01	219568.45	733702.73	99.96	0.00	0.01	0.01	219568.46	733702.74	99.96	0.01	0.02	0.01
99.697	219551.87	733675.42	99.68	0.01	0.01	0.02	219551.87	733675.42	99.68	0.01	0.01	0.02	219551.87	733675.46	99.67	0.01	0.03	0.03
99.5325	219531.11	733653.84	99.53	0.00	0.01	0.00	219531.11	733653.84	99.52	0.00	0.01	0.01	219531.10	733653.85	99.51	0.01	0.02	0.02
101.3385	219613.89	733764.38	101.32	0.01	0.01	0.02	219613.89	733764.37	101.32	0.01	0.00	0.02	219613.87	733764.37	101.32	0.03	0.00	0.02
102.4825	219663.44	733818.23	102.47	0.02	0.02	0.01	219663.44	733818.23	102.46	0.02	0.02	0.02	219663.43	733818.26	102.46	0.03	0.01	0.02
103.0355	219686.66	733849.30	103.03	0.01	0.02	0.01	219686.67	733849.27	103.02	0.00	0.01	0.02	219686.66	733849.30	103.02	0.01	0.02	0.02
104.037	219726.09	733898.44	104.04	0.03	0.02	0.00	219726.10	733898.43	104.04	0.02	0.01	0.00	219726.11	733898.44	104.04	0.01	0.02	0.00
106.803	219770.50	733954.53	106.80	0.01	0.31	0.00	219770.52	733954.81	106.79	0.03	0.03	0.01	219770.48	733954.83	106.79	0.01	0.01	0.01
108.9965	219827.44	733928.22	109.10	0.01	0.01	0.10	219827.43	733928.22	109.09	0.02	0.01	0.09	219827.44	733928.24	109.08	0.01	0.01	0.08
109.9405	219856.98	733911.07	109.98	0.02	0.01	0.04	219856.99	733911.05	109.98	0.01	0.01	0.04	219857.03	733911.02	109.97	0.03	0.04	0.03
110.521	219889.23	733899.93	110.55	0.01	0.01	0.03	219889.23	733899.93	110.54	0.01	0.01	0.02	219889.23	733899.94	110.53	0.01	0.00	0.01
119.8625	220309.61	733820.61	119.89	0.02	0.00	0.03	220309.61	733820.61	119.89	0.02	0.00	0.03	220309.59	733820.59	119.88	0.04	0.02	0.02
119.2225	220275.28	733823.56	119.24	0.00	0.01	0.02	220275.28	733823.56	119.23	0.00	0.01	0.01	220275.27	733823.56	119.23	0.01	0.01	0.01
118.5735	220239.73	733833.67	118.59	0.00	0.01	0.02	220239.72	733833.67	118.58	0.01	0.01	0.01	220239.73	733833.67	118.58	0.00	0.01	0.01
117.7405	220204.57	733840.17	117.76	0.00	0.01	0.02	220204.56	733840.15	117.75	0.01	0.01	0.01	220204.59	733840.17	117.74	0.02	0.01	0.00
116.6795	220163.57	733847.75	116.69	0.01	0.02	0.01	220163.57	733847.73	116.69	0.01	0.00	0.01	220163.57	733847.73	116.69	0.01	0.00	0.01
115.6765	220128.35	733854.27	115.69	0.01	0.00	0.01	220128.34	733854.28	115.68	0.00	0.01	0.00	220128.34	733854.29	115.68	0.00	0.02	0.00
114.654	220093.30	733860.98	114.68	0.01	0.01	0.03	220093.28	733860.96	114.66	0.01	0.01	0.01	220093.31	733860.98	114.65	0.02	0.01	0.00
113.4745	220052.49	733869.01	113.49	0.01	0.01	0.02	220052.50	733869.02	113.49	0.00	0.02	0.02	220052.50	733869.01	113.48	0.00	0.01	0.01
112.8105	220028.98	733873.68	112.82	0.00	0.01	0.01	220028.98	733873.68	112.82	0.00	0.01	0.01	220028.98	733873.66	112.81	0.00	0.01	0.00
112.033	219999.88	733879.74	112.04	0.01	0.01	0.01	219999.89	733879.73	112.04	0.00	0.00	0.01	219999.89	733879.75	112.03	0.00	0.02	0.00
110.5215	219938.46	733896.96	110.55	0.01	0.03	0.03	219938.46	733896.94	110.53	0.01	0.01	0.01	219938.47	733896.95	110.53	0.00	0.02	0.01
111.279	219972.34	733886.43	111.29	0.01	0.02	0.01	219972.32	733886.39	111.29	0.01	0.02	0.01	219972.34	733886.40	111.28	0.01	0.01	0.00

Feeling the accuracies



- The deviations between sections derived from the section tools on asphalt surface in all flights are similar to the coordinates elevation deviations.
- Since the surface on road asphalt is constant, the elevations should be equals for each section graph in each point.
- The video in the left show exactly the **deviations varies between 0 to 3 cm**.

Result investigations:

- Statistical results of the deviations for each flight by values:

Vertical – 60m

	dE [m]	dN [m]	dH [m]
Average	0.01	0.01	0.01
Standard Dev.	0.009	0.041	0.011
Median	0.008	0.007	0.010
Max	0.03	0.31	0.05

Diagonal – 60m

	dE	dN	dH
Average	0.01	0.01	0.01
Standard Dev.	0.009	0.008	0.009
Median	0.009	0.010	0.009
Max	0.04	0.04	0.04

Double grid – 60m

	dE	dN	dH
Average	0.01	0.01	0.01
Standard Dev.	0.011	0.008	0.008
Median	0.010	0.011	0.009
Max	0.04	0.04	0.04

Vertical – 40m

	dE	dN	dH
Average	0.01	0.01	0.02
Standard Dev.	0.012	0.010	0.014
Median	0.011	0.013	0.021
Max	0.06	0.04	0.06

Diagonal – 40m

	dE	dN	dH
Average	0.02	0.01	0.02
Standard Dev.	0.012	0.010	0.017
Median	0.013	0.011	0.011
Max	0.05	0.04	0.08

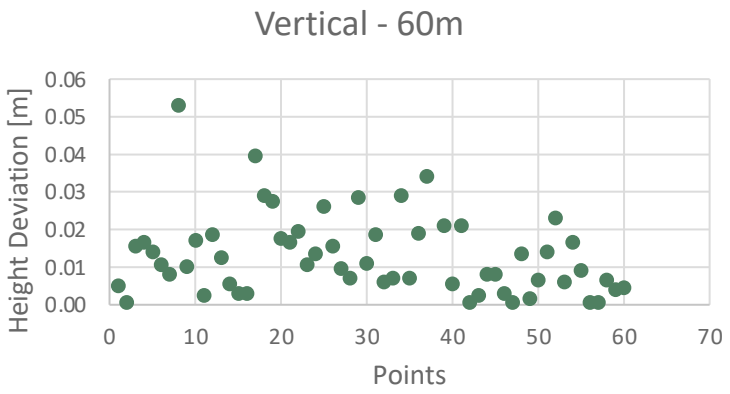
Double grid – 40m

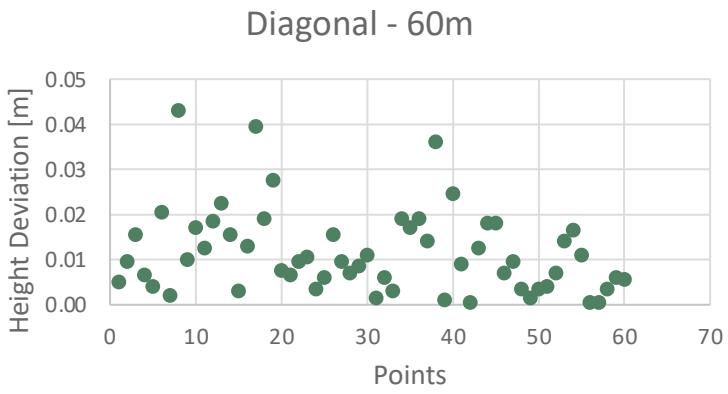
	dE	dN	dH
Average	0.02	0.02	0.03
Standard Dev.	0.014	0.016	0.028
Median	0.022	0.023	0.014
Max	0.05	0.09	0.13

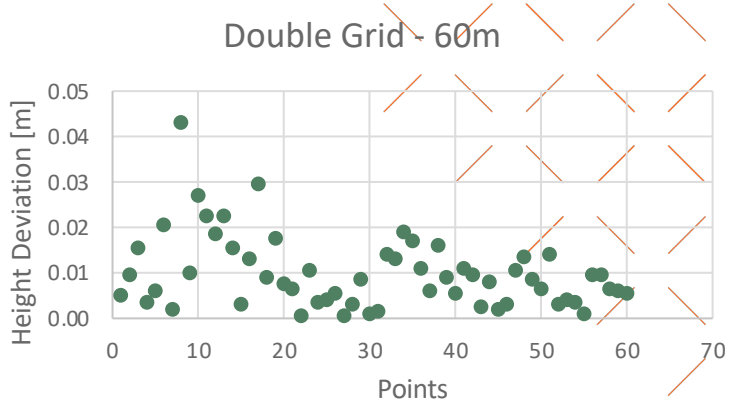
Both bad GCPs which were detected as 6 cm STDR

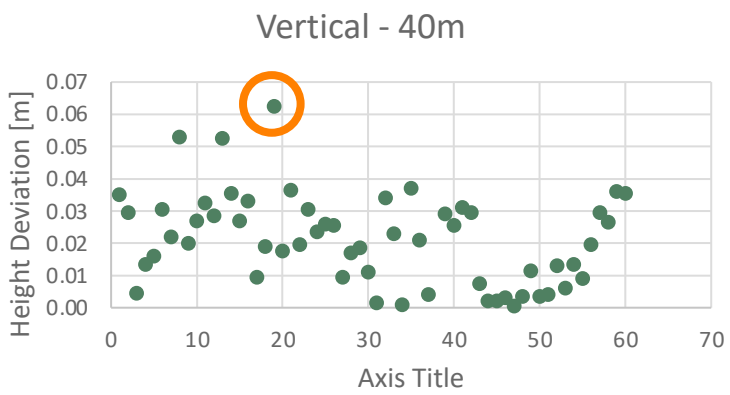
Result investigations:

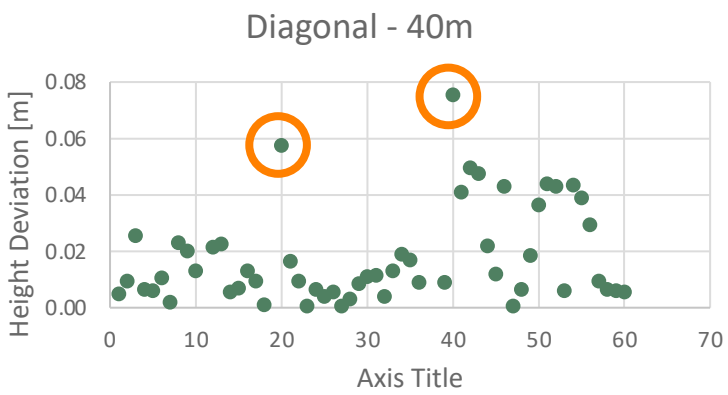
- Statistical results of the deviations for each flight by scattered graph:

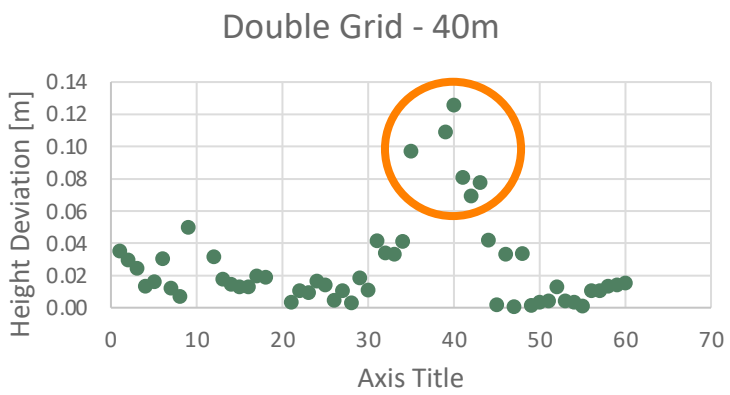






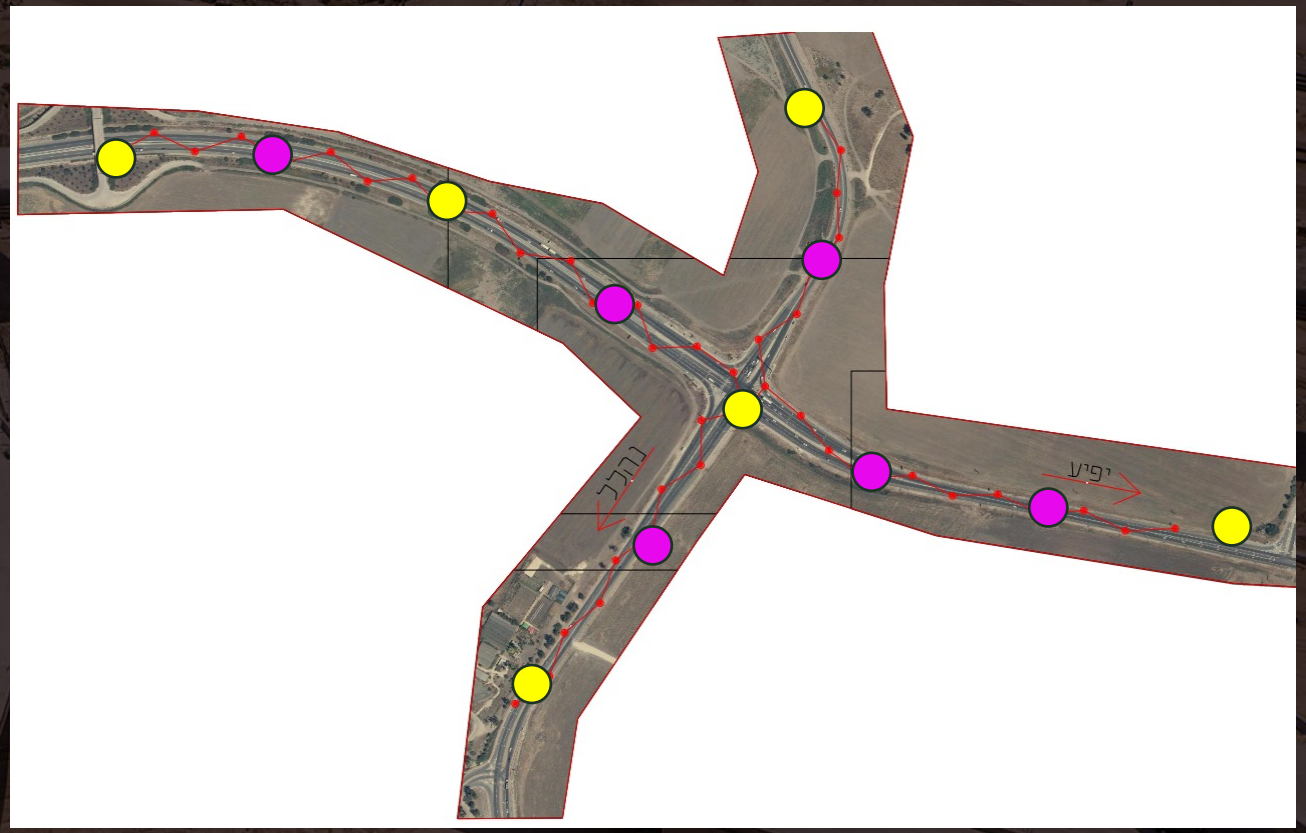






Dilution of the GCPs

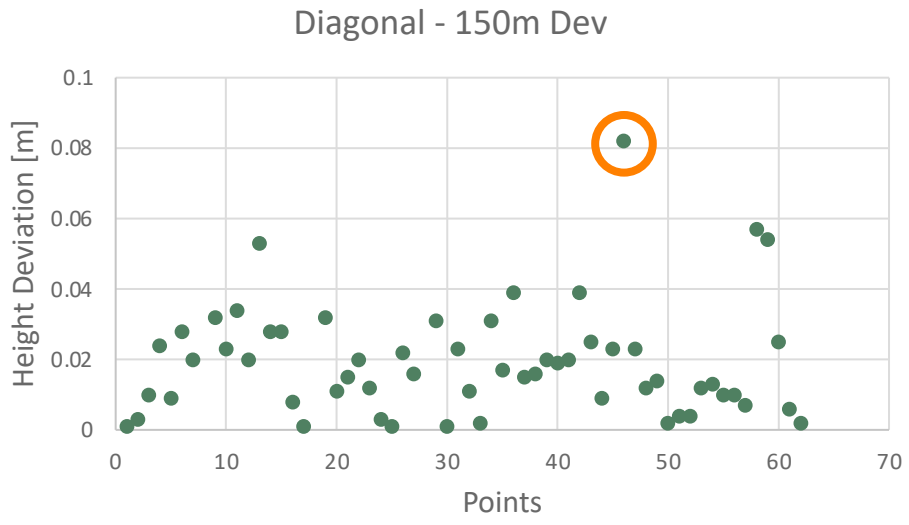
- For checking the **influence of the GCPs density on the model accuracies,** a flight with diagonal camera:
  - 60 m drone elevation
  - Taking images with AngH ~ 60-65 degrees.
- Two photogrammetric processes were done:
  - Using density of : one GCP every 300-350 m distance – **6 GCPs** in **yellow**.
  - Using density of : one GCP every 150 m distance – **12 GCPs**. Adding the **purple** GCPs
  -



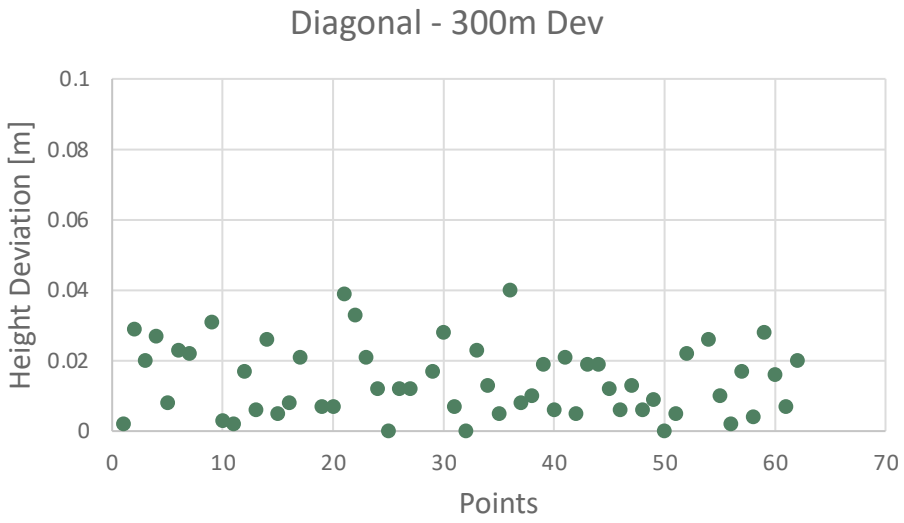
Result investigations:

- Statistical results of the deviations for each flight by scattered graphs:

	dH - 150m Dev. [m]	dH - 300m Dev. [m]
Average	0.0190	0.0140
Standard Dev.	0.0160	0.0100
Median	0.0160	0.0120
Max	**0.0820**	0.0400
Variance	0.0002	0.0001



12 GCP's



6 GCP's

3D texture model quality:

- Using double grid flights in one process reveals to higher texture model quality.
- The oblique one grid (diagonal AngH ~ 60-65 deg) texture model looks better than the vertical one grid one closer to the double grid but less than it.

One grid only

Double Grid

Recommendations

DatuBIM

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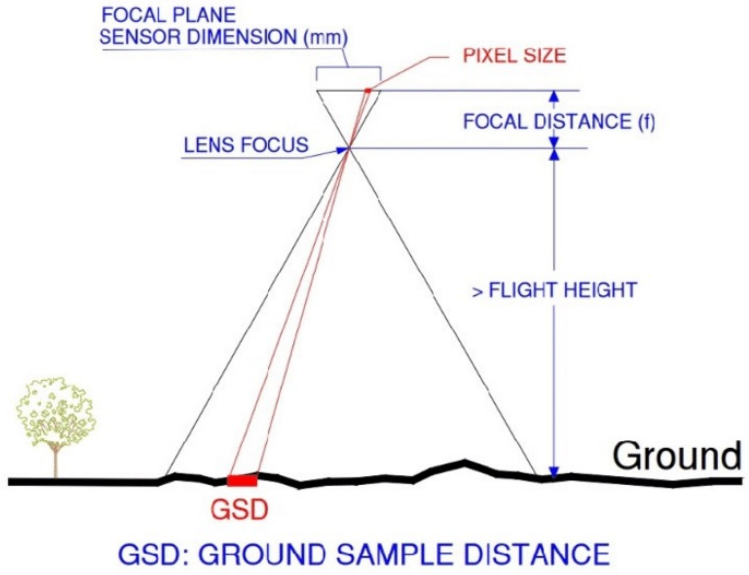
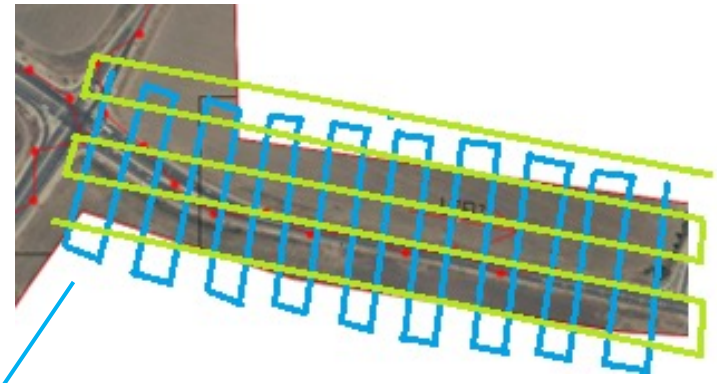
Summary & Recommendations

- 6 models were processed
- **All of the 6 models** provides an **accepted 1:250 scale mapping with 4 cm** in **3D in 95% confidence level** (CL). **2 cm in 68%** CL
- User Must Keep:
  - **80**% forward overlaps & **70**% side overlaps. **If the actual overlaps falls down the 60%, the accuracies will not be reliable**.
  - For achieving the above recommendation consider the speed of drone:
    - In sunny days take photos between 10:00 to 14:00 for reducin the negative impact of the shadow. Velocity can reach up to 5mph.
    - In cloudy days: Velocity should be up to 3 mph.
    - Camera must be a mechanical shutter camera. The bigger the sensor dimension is the better.
  - GSD must be 0.5 of the required mapping accuracy → the input fo calculate the drone flight elevation basing on the camera sensor spec.

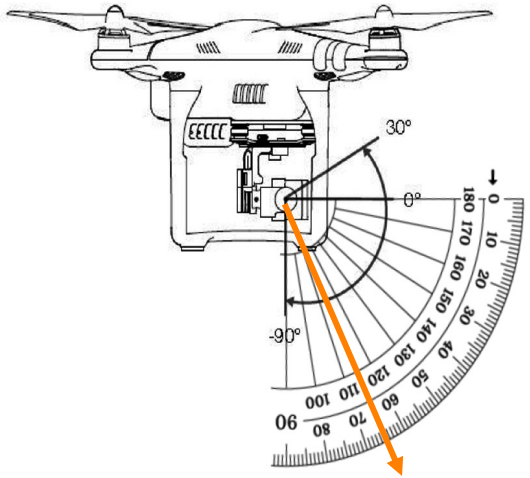


Summary & Recommendations

- Using RTK GPS without corrections we recommend adding **1 GCP every 1000-1200 ft** (330-400 m).
- For the best mapping results: take photos with AngH ~ 60-65 degree from the horizon in one grid but in the direction that leads to the maximum straight lines in the flight trajectory.
- Use double grid only when you ask for the best texture model.



Use the **blue** trajectory for one grid flight taking images with camera direction 60-65 deg from horizon.



Thank You!

Datumate