Politecnico di Milano - Courses on Photogrammetry
Laboratory report

First Name:	Gaia	Person code:	10505043
Last Name:	Vallarino	Matriculation:	996164
CFU group:	10	Date:	31/12/2022
Lab Topic:	02 - Drone Survey in Cassano d’Adda		

Description of the performed activity *(max 50 lines)*

The main goal of this lab was to create the DEM (Digital Elevation Model) and the orthophoto of a fluvial area in the proximity of Cassano d’Adda to perform further analysis; this was accomplished with an UAS, which was also one of the main reasons behind the location choice. Indeed, to fly the UAS, a location further away enough from any flight zone had to be picked. For what concerns the survey planning part of the lab, the flight had to be planned to reach the best accuracy possible for this type of survey; this was accomplished through the acquisition of photos in a almost nadiral direction parallel to the terrain’s surface. The flight also had to be planned and calibrated, which entailed the calculations of the GSD (0.01 m), the overlapping % in longitudinally and laterally (50% and 65% respectively), the flight parameters such as height of flight (50 m) and the actual path to be followed by the drone. The parameters were chosen in order to achieve a reasonable value of GSD and a higher overlapping, which also means to achieve better results later on during the BBA procedure. Obviously, a larger overlapping also means a higher number of images that needs to be acquired, thus leading to higher computational costs. See the results of the MATLAB computation in *fig.1-2*. **(12)**

Later, after all the necessary images were acquired, they were imported, together with the relative GCP (Ground Control Points) into Metashape. The whole procedure was done with images acquired by the first group, because the second group’s acquisition yielded problems in the image calibration. After a first low-accuracy BBA, the upload of some earlier-computed camera calibration parameters, and the subsequent collimation of the GCP on all images, a higher accuracy BBA was performed, but not before having unchecked ca. 20% of the GCP to keep as check points. These were picked from places were GCP were more densely distributed and avoiding as much as possible the borders of the image. After this step was performed, not all the images were oriented; this happened mostly for images taken above the central island that can be seen in *fig.3*, because of the presence of things easily moved by wind, such as water and trees. To overcome this issue, although not a most pressing one per se, two markers were added over objects not affected by the presence of wind. It is worthy of notice that this could also be solved by a flatter terrain (not achievable here) and by increasing the overlap of the photos, albeit, as mentioned above, correspondingly increasing the number of photos and computational cost of the process. After a first round of re-collimation of suspected outliers, and a second round of yet another BBA, we checked the accuracies retrieved against the target accuracy, which was supposed to be of around 10 cm. This should have given a fairly good idea of the actual achievable accuracy. As it can be seen in *fig. 4*, both the categories achieved comparable results, with the control points faring better than the check points (0.01m vs 0.08m). A comment that could be made is that higher errors in the z-direction, could be imputed to the accuracy of the camera mounted to the UAV, while higher errors in the XY plane would probably entail a wrong collimation by the user. **(19)**

Afterwards, the Point Cloud variance plot was computed (*fig. 5*) and it is of note that the variance is higher (red) whenever the terrain is not flat – e.g., in the abovementioned central island, where there are trees present. The border of the image, instead, does not show large problems, even though there is less overlapping in the photos, which could cause problems. One way to interpret this plot is that it represents the theoretical estimation error, and one could think of it like the diagonal of a C_{xx} matrix. This step was necessary to then launch an automatic algorithm that matches the tie points, which is the Dense Point Cloud. This process is performed by setting the resolution to “high” - which should amount to the original resolution - and the smoothing to “aggressive”. The results are shown in *fig.6*. The DC confidence is an index that shows from how many images each point is visible, and it can be filtered to show points available on more/less images. **(9)**

Subsequently, a DEM (Digital Elevation Model) was built, which is a model that would cause problems and distortions were the terrain not flat – phenomenon that can be observed in correspondence with the tree portion of the area. We also computed the orthomosaic by using the DEM as a reference surface and imposing the pixel size to 0.01 (a value close to the GSD). In *fig.3* it is possible to notice how there are some holes in the photo; this happens because either there are missing photos, or there are trees under the hypothesis of a flat terrain, or there is a hole in the DEM, thus making it impossible to rectify the image. **(6)**

At last, some computations are made over this model, and in particular, the analysis of possible paths for self-driving cars for testing over uneven roads was performed. This analysis can be better viewed in the attached documents *“test_path1”* and *“test_path2”* and in less detail in *fig.7-8*. The results show the comparison between path1 that has a more regular width and more regular terrain (cement plates) but steeper changes of altitude, and path2 that has a rougher terrain (potholes, curves, rougher asphalt) but less steep variations of altitude. **(6)**

As an additional deliverable, the camera calibration was performed anew, using the calibration photos acquired during the field trip. This calibration (“mycalibration.xml”) was then used to perform all the steps up to the BBA using the images of the survey. The results yielded by this procedure were not dissimilar to the ones provided in the beginning, as shown in *fig.9*. The estimated errors were not dissimilar either, albeit a bit higher than in the previous procedure. **(5) (57!!)**

Final Line Count: 57

Attachments

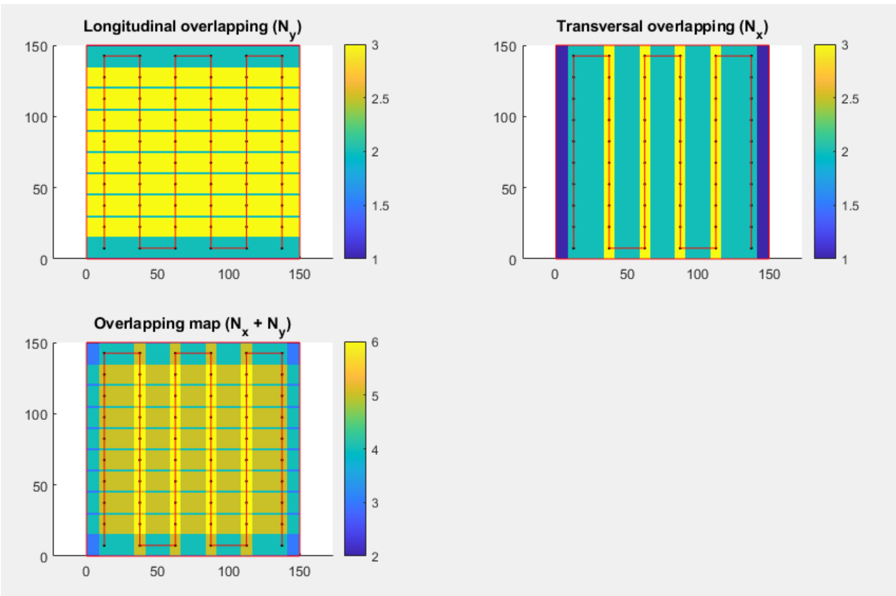
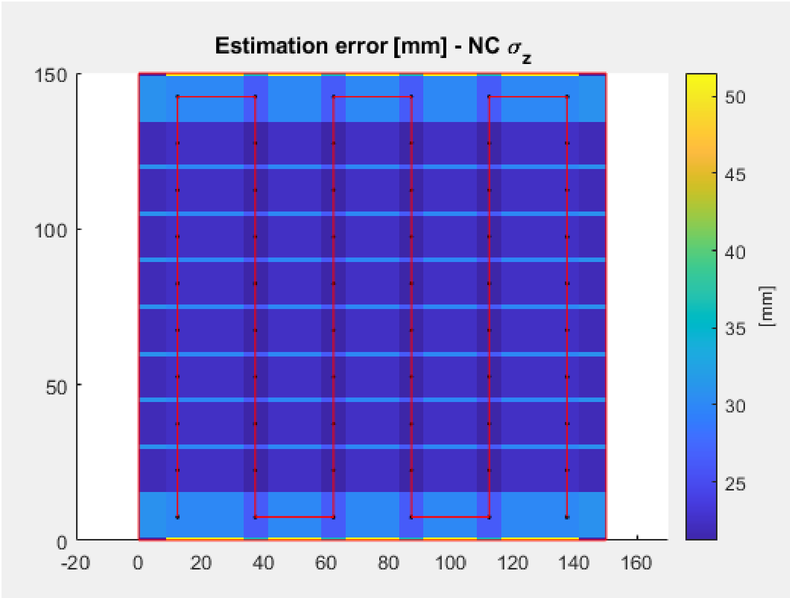


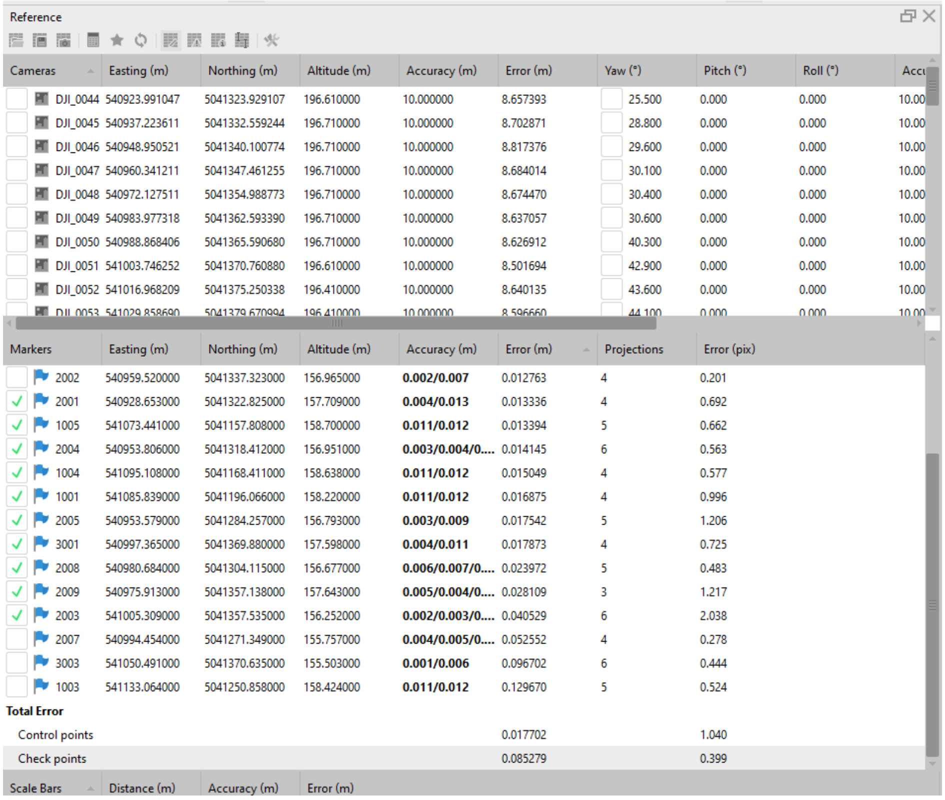
Fig. 1



Estimation error [mm] - NC σ_z
150
100
50
0
-20
0
20
40
60
80
100
120
140
160
50
45
40
35
30
25
[mm]

Fig. 2

Fig. 3



Reference

Cameras	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Yaw (°)	Pitch (°)	Roll (°)	Accu
DJI_0044	540923.991047	5041323.929107	196.610000	10.000000	8.657393	25.500	0.000	0.000	10.00
DJI_0045	540937.223611	5041332.559244	196.710000	10.000000	8.702871	28.800	0.000	0.000	10.00
DJI_0046	540948.950521	5041340.100774	196.710000	10.000000	8.817376	29.600	0.000	0.000	10.00
DJI_0047	540960.341211	5041347.461255	196.710000	10.000000	8.684014	30.100	0.000	0.000	10.00
DJI_0048	540972.127511	5041354.988773	196.710000	10.000000	8.674470	30.400	0.000	0.000	10.00
DJI_0049	540983.977318	5041362.593390	196.710000	10.000000	8.637057	30.600	0.000	0.000	10.00
DJI_0050	540988.868406	5041365.590680	196.710000	10.000000	8.626912	40.300	0.000	0.000	10.00
DJI_0051	541003.746252	5041370.760880	196.610000	10.000000	8.501694	42.900	0.000	0.000	10.00
DJI_0052	541016.968209	5041375.250338	196.410000	10.000000	8.640135	43.600	0.000	0.000	10.00
DJI_0053	541029.858690	5041379.670994	196.410000	10.000000	8.596660	44.100	0.000	0.000	10.00

Markers	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Projections	Error (pix)
2002	540959.520000	5041337.323000	156.965000	**0.002/0.007**	0.012763	4	0.201
2001	540928.653000	5041322.825000	157.709000	**0.004/0.013**	0.013336	4	0.692
1005	541073.441000	5041157.808000	158.700000	**0.011/0.012**	0.013394	5	0.662
2004	540953.806000	5041318.412000	156.951000	**0.003/0.004/0....**	0.014145	6	0.563
1004	541095.108000	5041168.411000	158.638000	**0.011/0.012**	0.015049	4	0.577
1001	541085.839000	5041196.066000	158.220000	**0.011/0.012**	0.016875	4	0.996
2005	540953.579000	5041284.257000	156.793000	**0.003/0.009**	0.017542	5	1.206
3001	540997.365000	5041369.880000	157.598000	**0.004/0.011**	0.017873	4	0.725
2008	540980.684000	5041304.115000	156.677000	**0.006/0.007/0....**	0.023972	5	0.483
2009	540975.913000	5041357.138000	157.643000	**0.005/0.004/0....**	0.028109	3	1.217
2003	541005.309000	5041357.535000	156.252000	**0.002/0.003/0....**	0.040529	6	2.038
2007	540994.454000	5041271.349000	155.757000	**0.004/0.005/0....**	0.052552	4	0.278
3003	541050.491000	5041370.635000	155.503000	**0.001/0.006**	0.096702	6	0.444
1003	541133.064000	5041250.858000	158.424000	**0.011/0.012**	0.129670	5	0.524
Total Error							
Control points					0.017702		1.040
Check points					0.085279		0.399

Scale Bars	Distance (m)	Accuracy (m)	Error (m)

Fig. 4

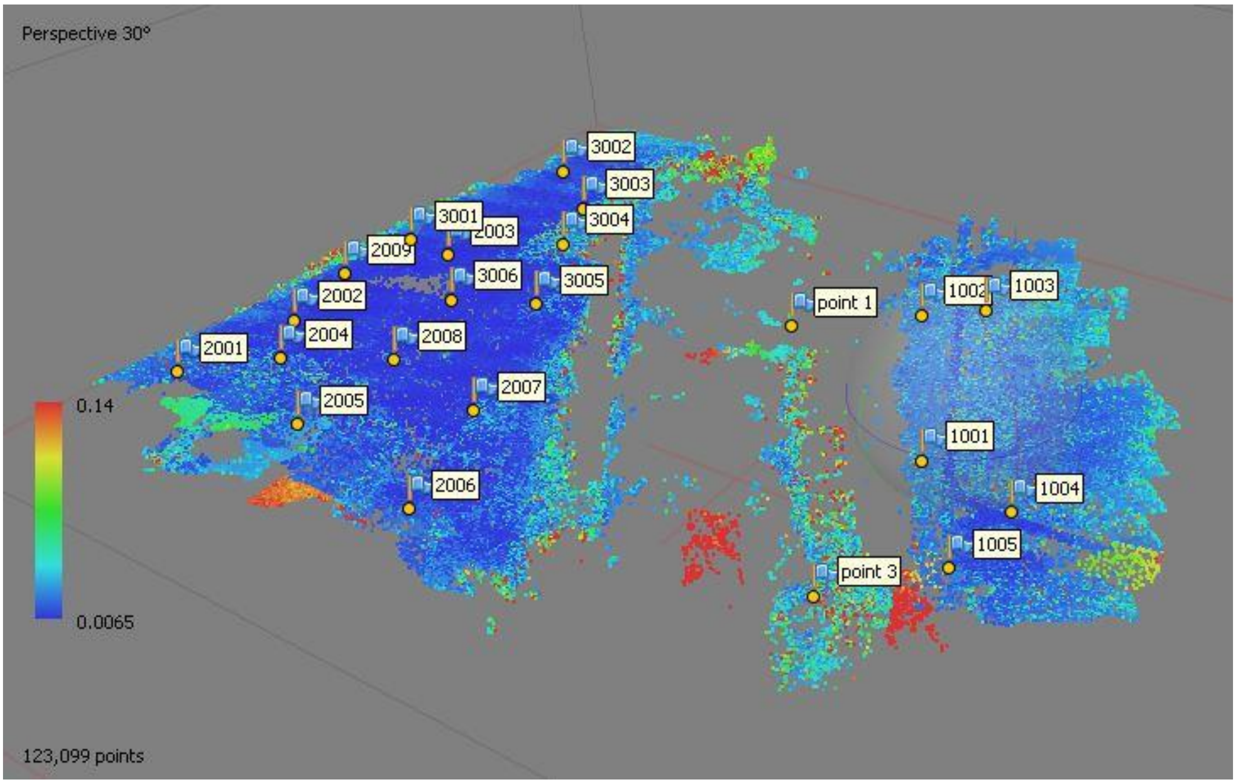


Fig. 5

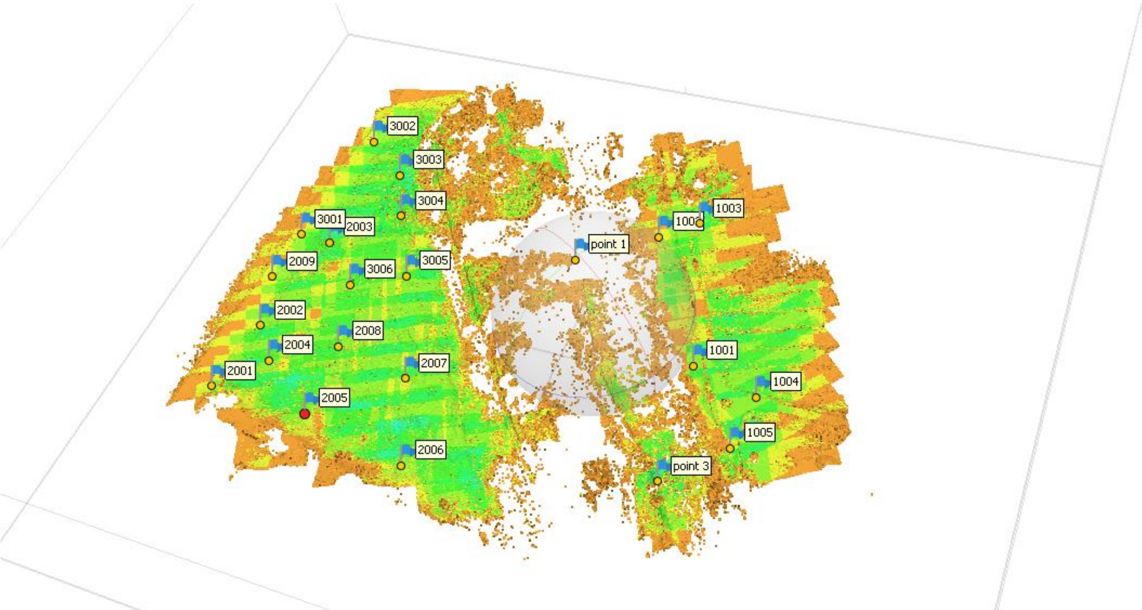

3002
3003
3004
3001
2003
2009
3006
3005
2002
2008
2004
2007
2001
2005
2006
point 1
1002
1003
1001
1004
1005
point 3

Fig. 6

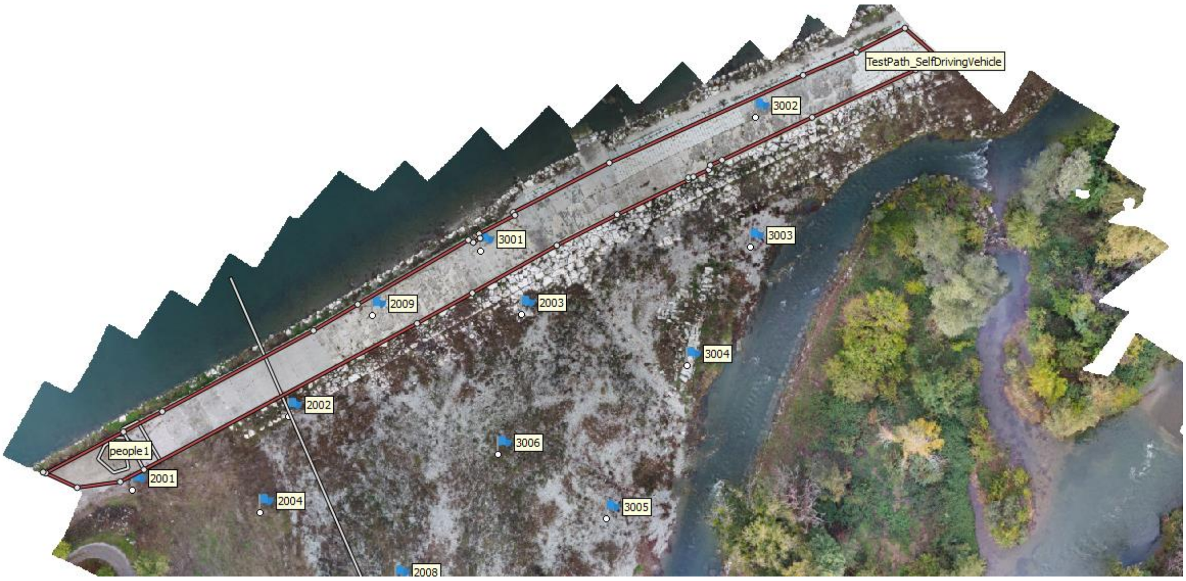

TestPath_SelfDrivingVehicle
3002
3001
3003
2009
2003
3004
2002
3006
people 1
2001
2004
3005
2008

Fig. 7

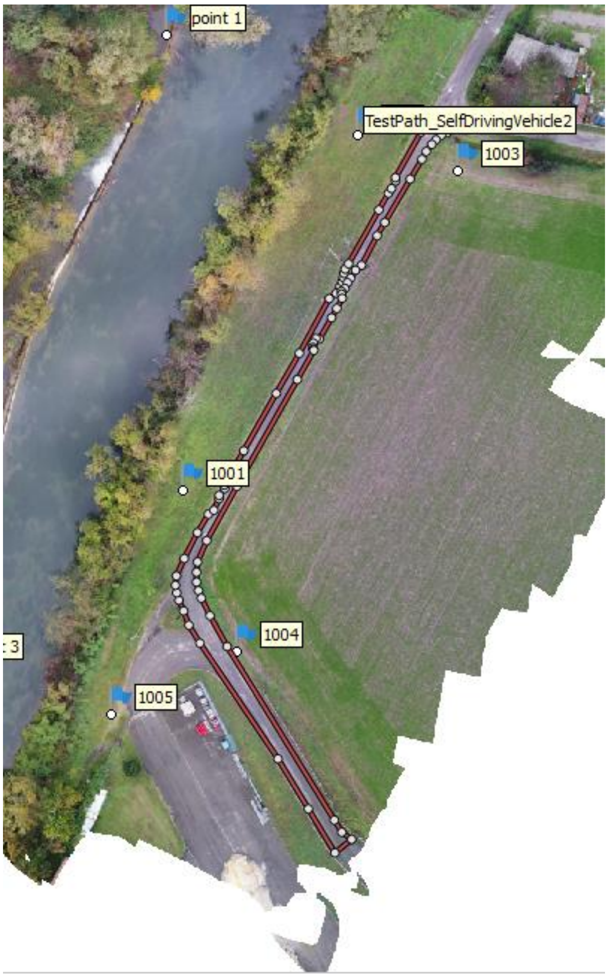


Fig. 8

New parameters

Total	**2.34983**	**1.72603**	**1.56744**	**3.31025**	**1.924**

Table 4. Control points.
X - Easting, Y - Northing, Z - Altitude.

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
1002	8.51908	-5.48731	0.385732	10.1407	0.347 (4)
1005	-3.41763	-9.74712	-17.4822	20.3055	0.503 (5)
2003	4.06247	-6.2201	1.12147	7.51339	0.873 (6)
3004	-0.779819	6.20282	0.349003	6.26138	0.693 (6)
point 1					0.032 (3)
point 3					0.701 (6)
Total	**5.03405**	**7.11129**	**8.76291**	**12.3572**	**0.662**

Table 5. Check points.
X - Easting, Y - Northing, Z - Altitude.

Old parameters

Total	**2.65266**	**2.34362**	**1.75848**	**3.9524**	**2.591**

Table 4. Control points.
X - Easting, Y - Northing, Z - Altitude.

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
1002	7.96456	-5.87652	1.23789	9.97497	0.418 (4)
1005	-4.59551	-12.8498	-11.1513	17.6235	0.625 (5)
2003	4.61231	-5.698	-0.71871	7.36595	0.801 (6)
3004	-0.253757	6.7968	-0.840814	6.85331	0.597 (6)
point 1					0.049 (4)
point 3					1.027 (6)
Total	**5.14516**	**8.34139**	**5.63709**	**11.3061**	**0.642**

Table 5. Check points.
X - Easting, Y - Northing, Z - Altitude.

Fig.9 – New parameters vs Old parameters