NUMERO: **2464A** ANNO: 2020

A P P U N T I

STUDENTE: Chiforeanu Loredana

MATERIA: Geomatics exercise exam - Prof. Piras, Dabove

2017/2018

POLITECNICO DI TORINO

Master Course in Civil Engineering
Geomatics course

REPORT

Collection and analysis of the activities done in the laboratory hours
+
Step by step of used softwares with screenshots
+
EXAM QUESTIONS

Student: Loredana Mihaela Chiforeanu

Professors: Marco Piras
Paolo Dabove

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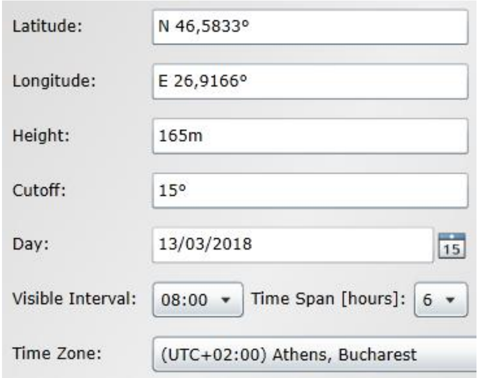
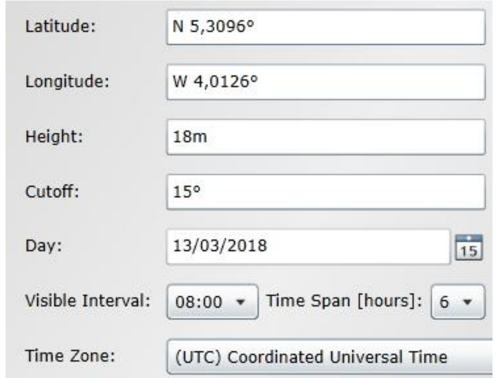
EX 1.

Let's imagine to realize a planning in different cities in order to observe the differences between satellite availability.
Two cities have been chosen: the time interval varies from 8:00 am to 2:00 pm. Using the Trimble Online Software, the following outputs show the differences that can occur depending on our chosen parameters.

City	Bacau (Romania, Europe)	Abidjan (Costa d'Avorio, Africa)
Settings		
	These are the characteristics of the two cities. The date is 13/3/18. Bacau is situated in East Europe. Abidjan is situated near the Equator in West Africa. The receiver coordinates are needed, as well as the cutoff angle and the time window of our interest.	
GPS		
	These are the GPS only satellites available on that day. The red cross indicates that the satellite is out of order.	

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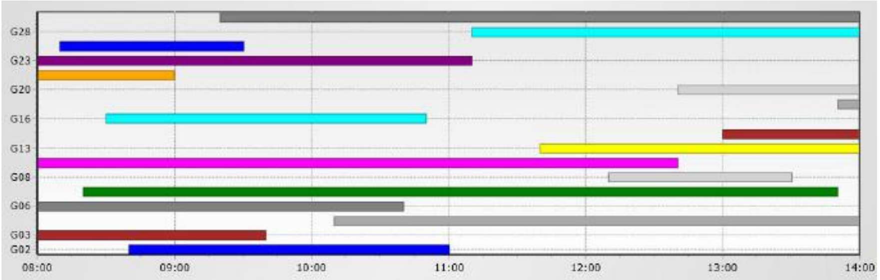
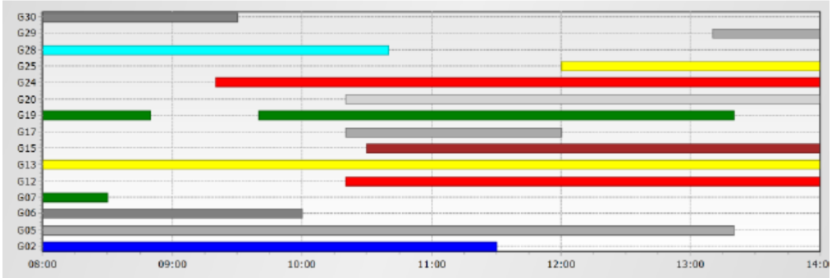
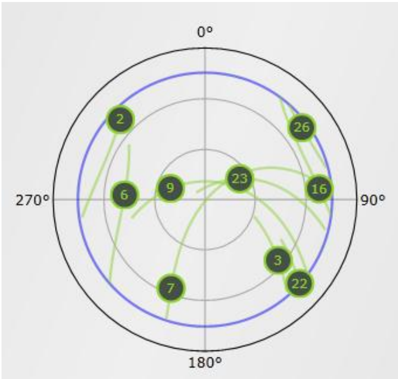
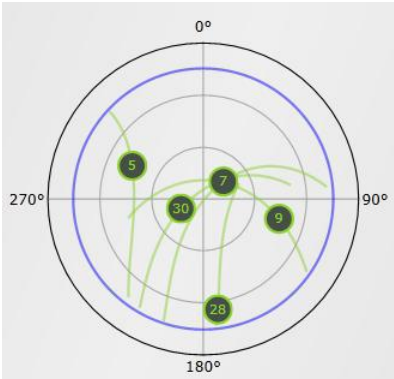
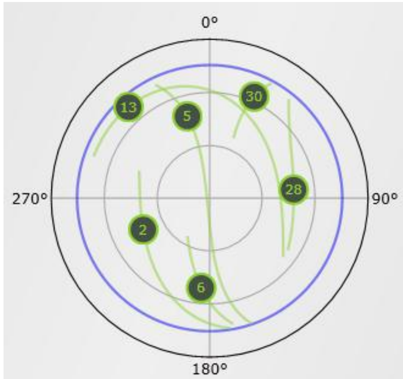
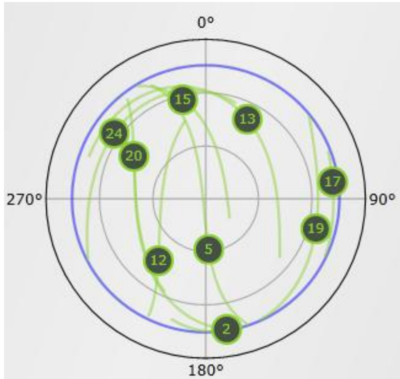
<table>
<tr><td>Visibility</td><td>
</td><td>
</td></tr>
<tr><td></td><td colspan="2">Also in these graphs we can count the number of available satellites at different hours. We find again that there are 9 satellites at 9:00 and 5 at 11:30 for Bacau, while there are 6 at 9:00 and 9 at 11:30 for Abidjan.
The more a satellite is visible the better for the survey, otherwise we have lot's of errors due to loss of visibility.
It seems that in Bacau there are few satellites visible for more than 3 hours while it's the contrary in Abidjan.</td></tr>
<tr><td>Skyplot</td><td>9:00 

11:30 
</td><td>9:00 

11:30 
</td></tr>
<tr><td></td><td colspan="2">Here there are the skyplots representations: they show us the variability of the satellites in time and their trajectories, in terms of Azimuth (concentric circles: 0°-360°) and Elevation (radii: 0°-90°).
We can observe that in the Bacau region the Northern part isn't covered by satellites, while quite all the area of Abidjan is covered. Of course the number of satellites differ for the reasons we said before.
[The areas around the pole are not very well covered by the satellites because their orbits are inclined by 55° so they're seen at very low cutoff angles but of course the measurements are affected by the tropospheric errors, so for example making a survey at the Earth's poles is very difficult.]</td></tr>
</table>

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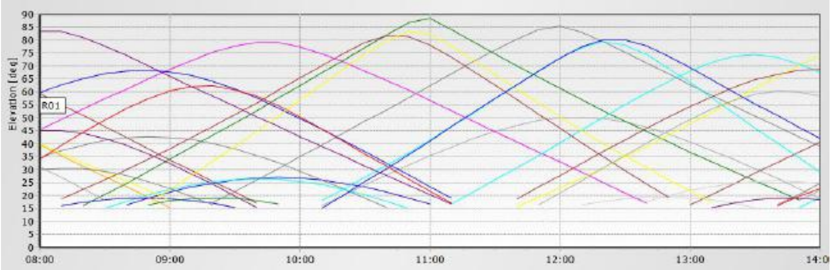
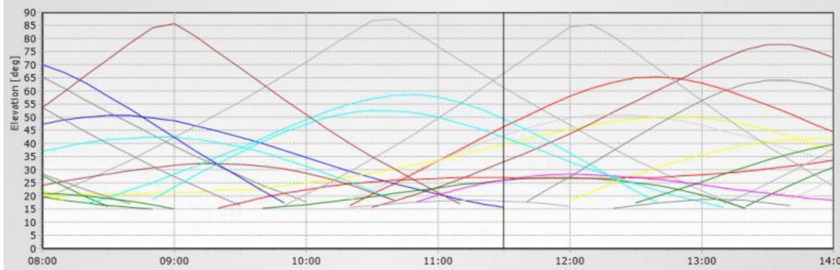
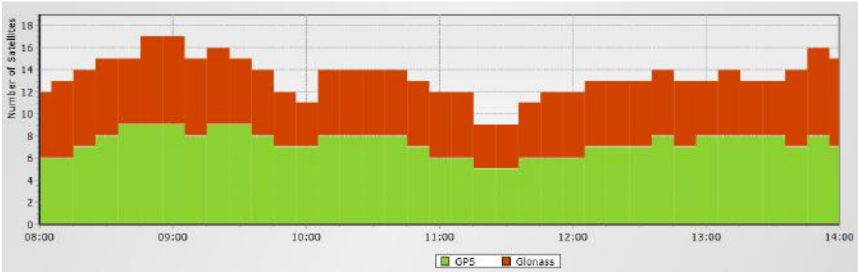
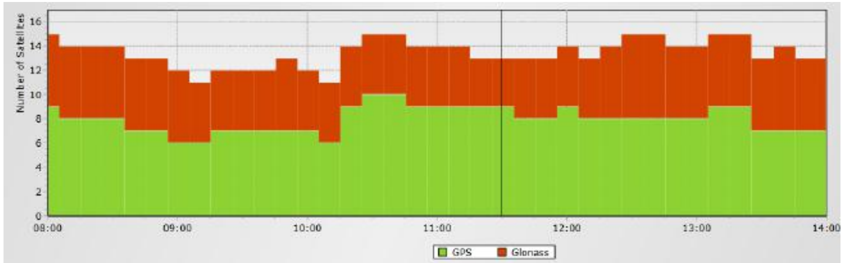
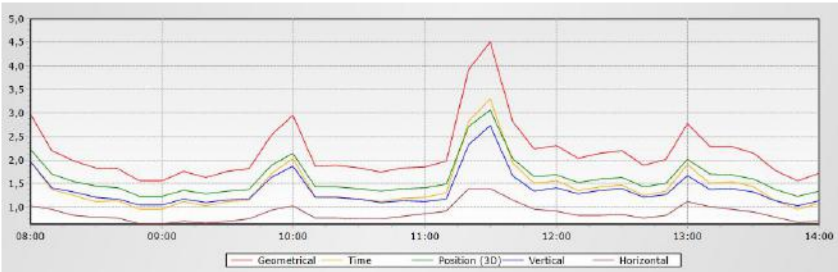
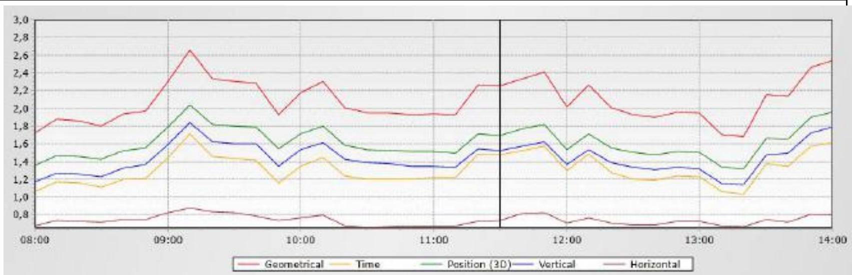
Elevation		
	Of course the number of satellites has been increased but still in Bacau the range of elevations is wide while in Abidjan it's more concentrated amog lower values.	
Nr of satellites		
	We can see that the overall number of satellites is bigger for Bacau (17 at 9:00) than for Abidjan (15 in the afternoon). The lower numbers are respectively 9 at 11:30 and 11 in the morning. For Bacau area there is a more evident variation of avaibility between morning and afternoon while for the Abidjan area the availability is constant.	
DOPs		
	As a reflection of the availability during the time interval and of the total number of satellites, the DoPs are 2.0-2.5 for Bacau but with evident peaks (4.5), while in Abidjan the DoPs are constant (2.0-2.5) with small peaks. The PDoF have decreased (1.4-1.6) due to the bigger availability.	

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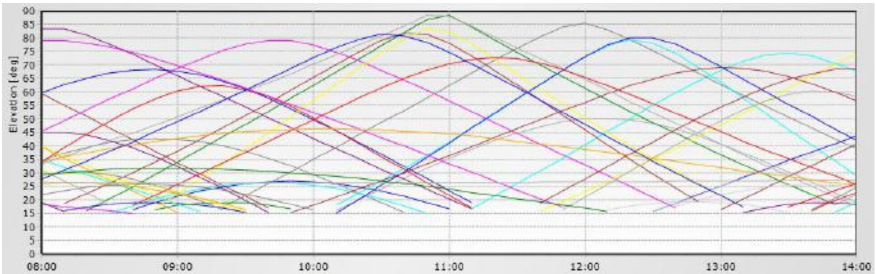
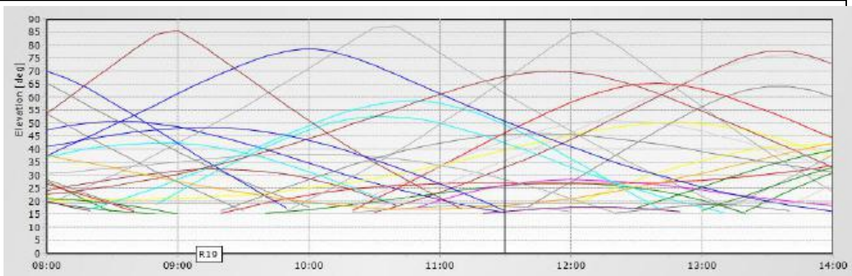
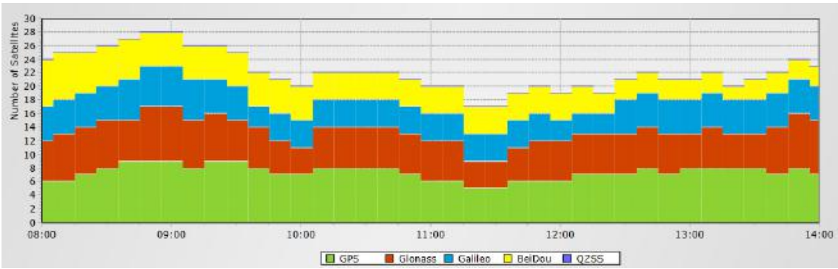
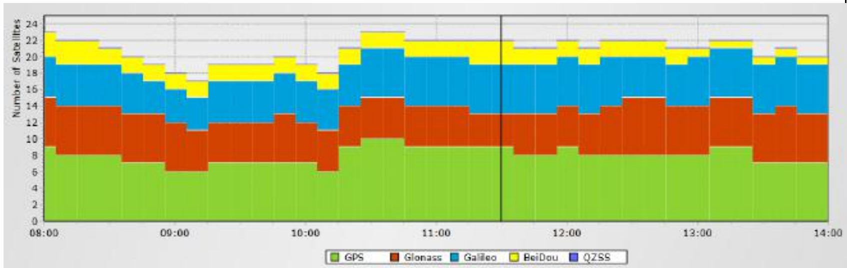
<table>
<tr><td></td><td>11:30

</td><td>11:30

</td></tr>
<tr><td>GNSS</td><td>
</td><td>
</td></tr>
<tr><td></td><td colspan="2">Now we compare the situations by adding all the constellations.</td></tr>
<tr><td>Elevation</td><td>
</td><td>
</td></tr>
<tr><td></td><td colspan="2">Of course the number of satellites has been increased but still in Bacau the range of elevations is wide while in Abidjan it’s more concentrated amog lower values.</td></tr>
<tr><td>Nr of satellites</td><td>
</td><td>
</td></tr>
</table>

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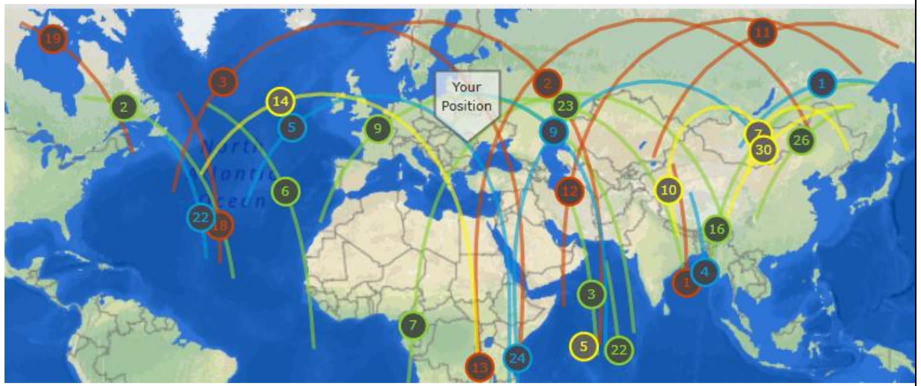
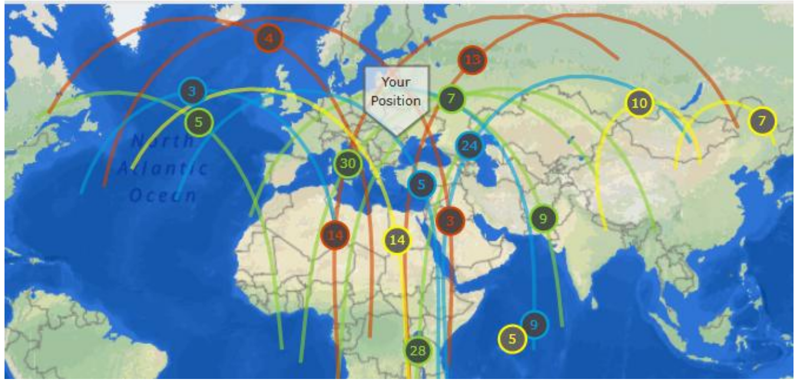
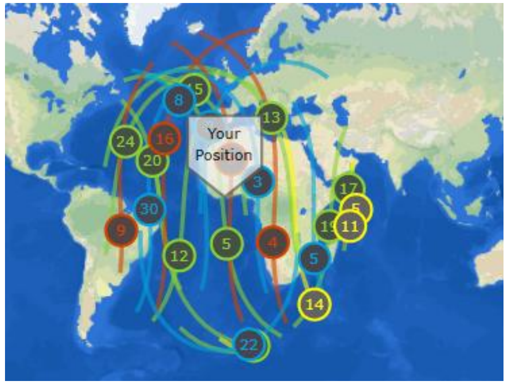
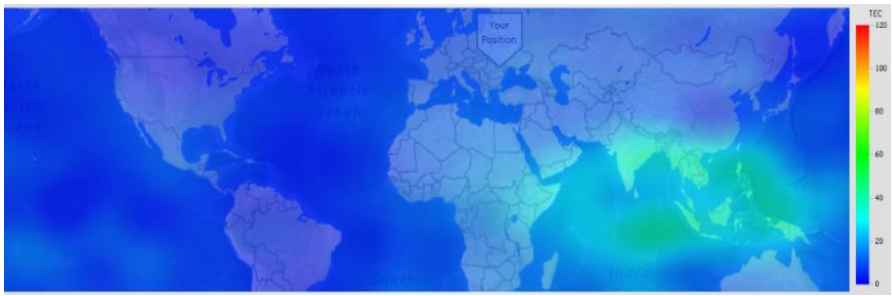
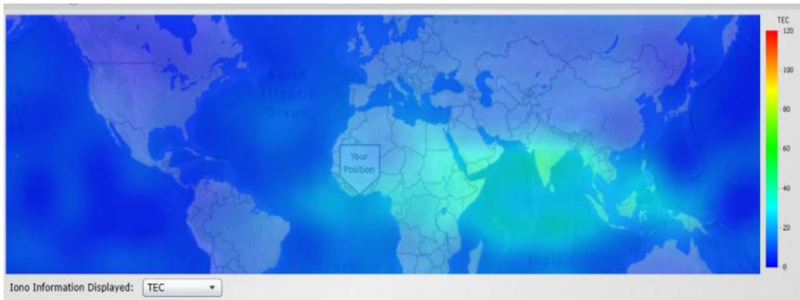
World view	9:00 	9:00 
	11:30 	11:30 
	We observe that also in the global maps the covered areas now are wider.	
Iono map	11:30 	11:30 

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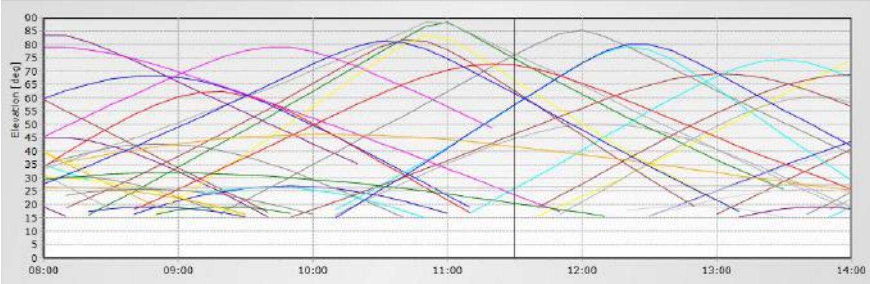
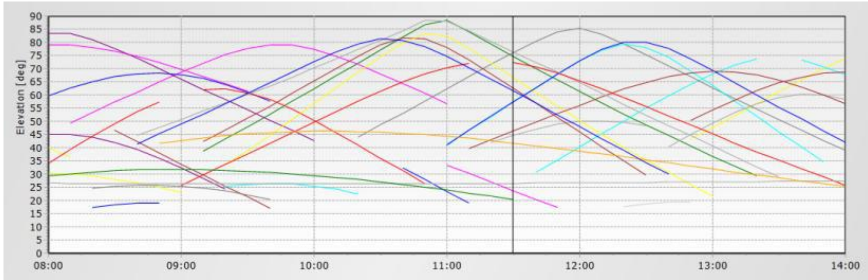
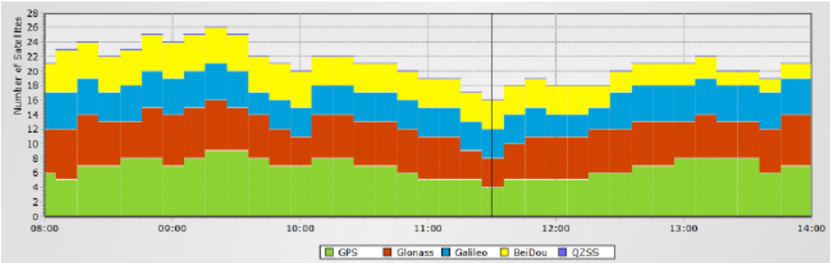
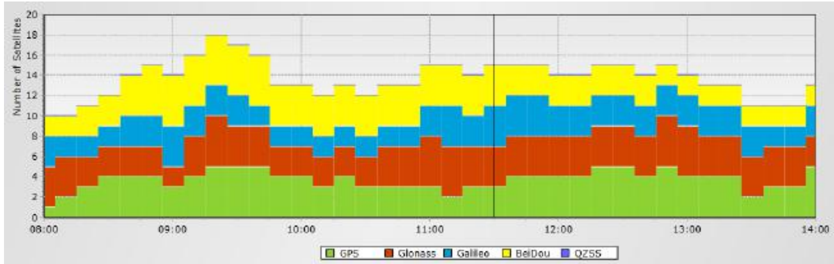
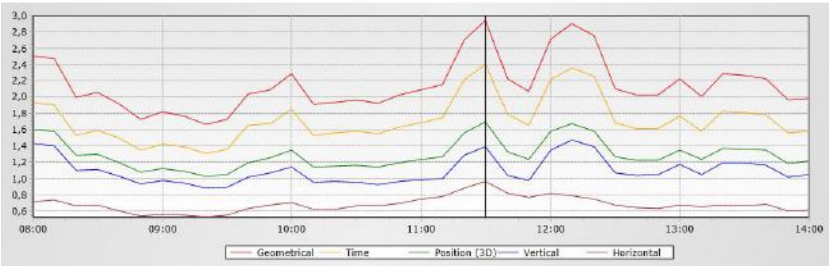
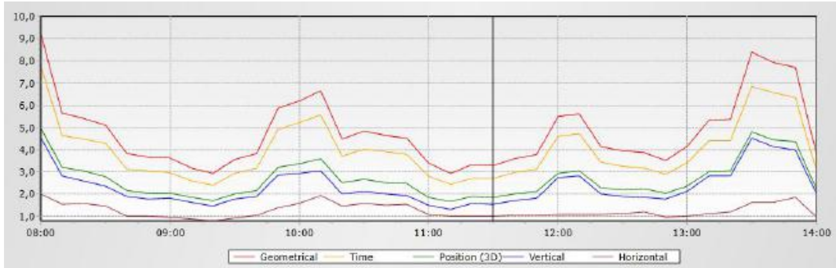
Elevation		
	The obstacle doesn't allow to see satellites under its elevation. But this case doesn't affect so much the overall availability.	Here there are more obstacles having bigger elevations, which affect more the availability.
Nr of satellites		
	As a consequence, the total number of satellites can be the same (case1) or lowered (case2) .	
DOPs		
	It's easy to notice that in case 2 the DoPs are very high, up to 9, while in case 1 they're not much affected by the type of obstruction.	

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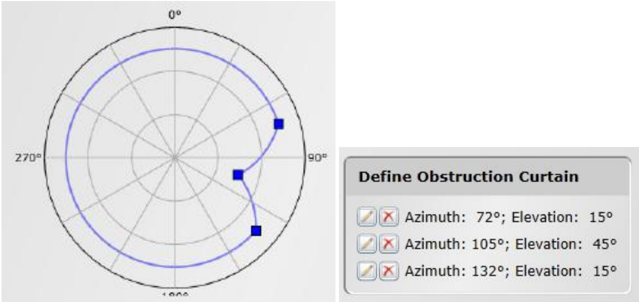
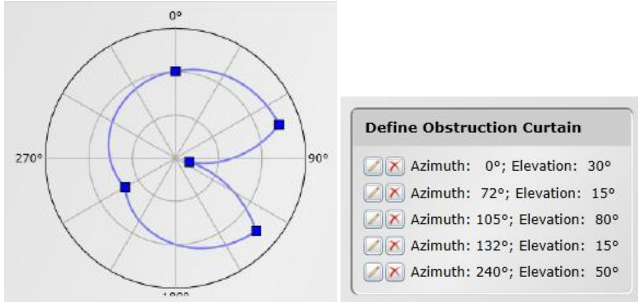
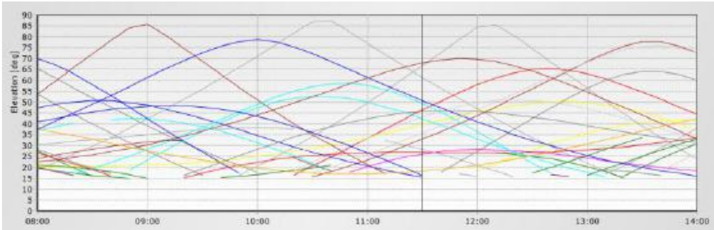
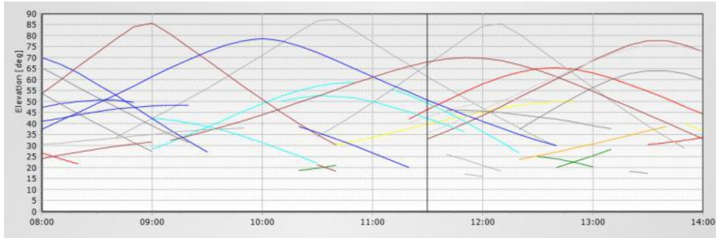
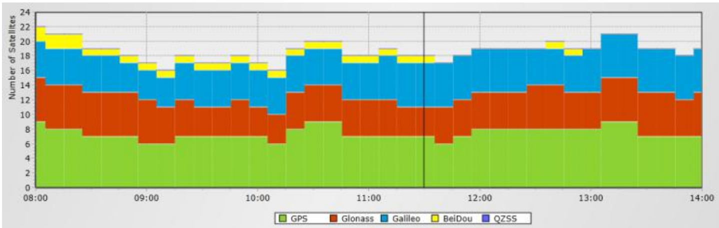
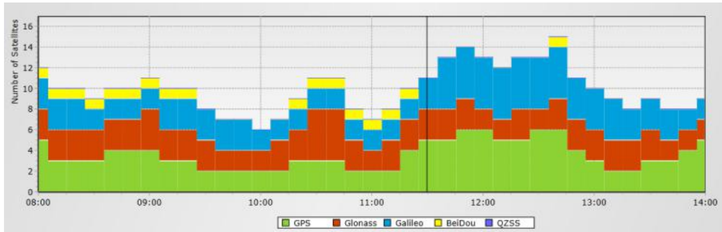
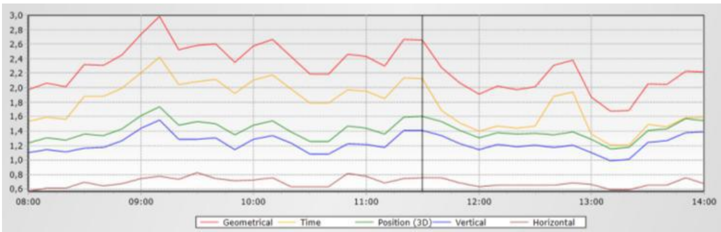
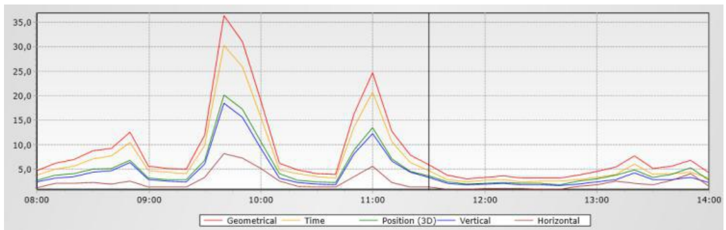
Abidjan GNSS	Obstruction 1	Obstruction 2
Settings		
	Also for Abidjan the same types of obstructions have been made. The observations can be the same, we just show briefly the outputs.	
Elevation		
Nr of satellites		
DOPs		
	It is interesting to note that if in case 1 the DoPs haven't rised so much with respect to the non obstructed case, in case 2 the max HDoP has reached a peak value of 35 while the PDoP has raised up to 20, which means that measures could be inaccurate by as much as 300m.	

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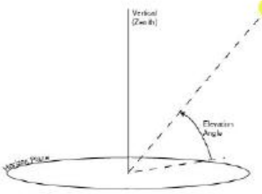
EX 2.

Given the coordinates (x,y,z) of a satellite and those of a station (λ, φ), define the (x,y,z) coordinates of the station and find the satellite's azimuth and elevation, using the following formulas.



$$\begin{pmatrix} e \\ n \\ u \end{pmatrix} = \begin{bmatrix} -\sin\lambda & \cos\lambda & 0 \\ -\sin\varphi\cos\lambda & -\sin\varphi\sin\lambda & \cos\varphi \\ \cos\varphi\cos\lambda & \cos\varphi\sin\lambda & \sin\varphi \end{bmatrix} \begin{pmatrix} X - X_i \\ Y - Y_i \\ Z - Z_i \end{pmatrix}$$

$$\begin{cases} X = \dfrac{a \cdot \cos\varphi \cdot \cos\lambda}{W} \\ Y = \dfrac{a \cdot \cos\varphi \cdot \sin\lambda}{W} \\ Z = \dfrac{a \cdot (1 - e^2) \cdot \sin\varphi}{W} \end{cases} \quad \text{where} \quad W = \sqrt{1 - e^2 \cdot \sin^2\varphi}$$

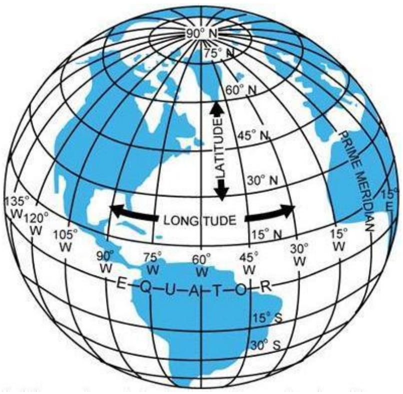
Where
e,n,u = local coordinates
φ,λ = station coordinates (geographic)
X,Y,Z = satellites position (ECEF)
Xi, Yi, Zi, = station position (ECEF)

WGS84

Parameter	Notation	Value
semi-major axis	a	6378137.0 m
flattening	f	1 / 298.257223

$e^2 = 1 - b^2/a^2 = 2f - f^2$

$$azimuth = atn\frac{u}{\sqrt{n^2 + e^2}} \qquad elev = atn\frac{e}{n}$$



EX.

Xsat = 15487292,829 m
Ysat = 6543538,932 m
Zsat = 20727274,429 m

Latitude (station) = 45° 3' 48.114''
Longitude (station) = 7°39' 40.605''

Goal

To define X, Y, Z station

To estimate AZ, EL of the SATELLITE

Solution 2.

We have all the formulas needed to do the transformations, so we can follow the scheme:

Station: (λ, φ) → (Xi,Yi,Zi) in WGS84

Satellite: (X,Y,Z) in WGS84 + (Xi,Yi,Zi) in WGS84 → (e,n,u) in local coord. → (azimuth,elevation)

I implemented this calculus using Matlab Software.

Matlab code

```
clear all;  close all;  clc;

%satellite coordinates in WGS84
x_sat= 15487292.829;   %[m]
y_sat=   6543538.932;  %[m]
z_sat= 20727274.429;   %[m]

%station latitude
fi_grade = 45;              %[°]
fi_primes = 3;              %[']
fi_seconds = 48.114;        %['']

%station longitude
lambda_grade = 7;              %[°]
lambda_primes = 39;            %[']
lambda_seconds = 40.605;       %['']

%transformation from grades to radians
fi_deg=fi_grade + fi_primes/60 + fi_seconds/3600;       %[°]
```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EX 3.

Given the coordinates (x,y,z) of a satellite and those of a station (λ ,φ), calculate the dilution of precision DoP using the following formulas.

$$\rho_i^j(t) = \sqrt{(X^j(t) - X_i)^2 + (Y^j(t) - Y_i)^2 + (Z^j(t) - Z_i)^2}$$

$$D1 = \frac{Xsat - Xrec}{\rho} \qquad D2 = \frac{Ysat - Yrec}{\rho} \qquad D3 = \frac{Zsat - Zrec}{\rho} \qquad D4 = -1$$

$$D = \begin{bmatrix} D1s1 & D2s1 & D3s1 & -1 \\ D1s2 & D2s2 & D3s2 & -1 \\ \dots & \dots & \dots & \dots \\ D1sn & D2sn & D3sn & -1 \end{bmatrix}$$

Geographic coordinates of the station

$$Qxx = (D^T D)^{-1} \qquad Quu = R Qxx R^T \qquad R = \begin{bmatrix} -\sin\lambda & \cos\lambda & 0 \\ -\sin\varphi\cos\lambda & -\sin\varphi\sin\lambda & \cos\varphi \\ \cos\varphi\cos\lambda & \cos\varphi\sin\lambda & \sin\varphi \end{bmatrix}$$

Coordinate of the station $\varphi = 45°3'48''$, $\lambda = 7°39'41''$, $h=0m$

$$Quu = \begin{pmatrix} XDOP^2 & & & \\ & YDOP^2 & & \\ & & VDOP^2 & \\ & & & TDOP^2 \end{pmatrix}$$

Satellite coordinates

sat	X	Y	Z
1	22504974,806	13900127,123	-2557240,727
2	-3760396,280	-17947593,853	19494169,070
4	9355256,428	-12616043,006	21189549,365
7	23959436,524	5078878,903	-10562274,680
10	10228692,060	-19322124,315	14550804,347
13	23867142,480	-3892848,382	10941892,224
17	21493427,163	-15051899,636	3348924,156
20	14198354,868	13792955,212	17579451,054
23	18493109,722	4172695,812	18776775,463
31	-8106932,299	12484531,565	22195338,169
32	8363810,808	21755378,568	13378858,106

$$HDOP = \sqrt{XDOP^2 + YDOP^2}$$

$$PDOP = \sqrt{XDOP^2 + YDOP^2 + VDOP^2}$$

$$GDOP = \sqrt{XDOP^2 + YDOP^2 + VDOP^2 + TDOP^2}$$

Solution 3.

Due to the relative geometry of any given satellite to a receiver, the precision in the pseudorange of the satellite translates to a corresponding component in each of the four dimensions of position measured by the receiver (i.e. x,y,z and t). The precision of multiple satellites in view of a receiver combine according to the relative position of the satellites to determine the level of precision in each dimension of the receiver measurement. When visible navigation satellites are close together in the sky, the geometry is said to be weak and the DOP value is high; when far apart, the geometry is strong and the DOP value is low. If they overlap at right angles, the greatest extent of the overlap is much smaller than if they overlap in near parallel. Thus a low DOP value represents a better positional precision due to the wider angular separation between the satellites used to calculate a unit's position. Other factors that can increase the effective DOP are obstructions such as nearby mountains or buildings.

DOP can be expressed as a number of separate measurements:

- HDOP – horizontal dilution of precision
- VDOP – vertical dilution of precision
- PDOP – position (3D) dilution of precision
- TDOP – time dilution of precision

These values follow mathematically from the positions of the usable satellites. Signal receivers allow the display of these positions (skyplot) as well as the DOP values.

```
     -8106932.299 12484531.565 22195338.169
     8363810.808  21755378.568 13378858.106];

%cycle for computing pseudorange
for i=1:11
    for j=1:3
        Rho(i,j)=(sat(i,j)-s(j))^2;
    end
end
rho=zeros(11,1);
for h=1:11
    rho(h)=sqrt(sum(Rho(h,:)));
    end
%cycle for finding D matrix [4x4]
G=zeros(11,3);
O=-1*ones(11,1);

for k=1:11
    for l=1:3
    G(k,l)=(sat(k,l)-s(l))/rho(l);
    end
end
D=[G,O];
%find Qxx, but use G (3x3)
Qxx=inv(G'*G);
R=[-sin(lambda_rad)                 cos(lambda_rad)               0
   -sin(fi_rad)*cos(lambda_rad)    -sin(fi_rad)*sin(lambda_rad)   cos(fi_rad);
   cos(fi_rad)*cos(lambda_rad)     cos(fi_rad)*sin(lambda_rad)    sin(fi_rad)];
Quu=R*Qxx*R';
d=diag(Quu)
HDOP=sqrt(d(1)+d(2));
PDOP=sqrt(d(1)+d(2)+d(3));
GDOP=PDOP;
fprintf('HDOP = %.3f;\nPDOP = %.3f;\nGDOP = %.3f.',HDOP,PDOP,GDOP)
```

Results

D=[0.7677 0.5269 -0.3227 -1.0000
-0.3505 -0.7350 0.6866 -1.0000
0.2079 -0.5237 0.7642 -1.0000
0.8296 0.1774 -0.6891 -1.0000
0.2451 -0.7895 0.4604 -1.0000
0.8257 -0.1781 0.2952 -1.0000
0.7246 -0.6203 -0.0523 -1.0000
0.4141 0.5227 0.5990 -1.0000
0.5969 0.1415 0.6538 -1.0000
-0.5355 0.4709 0.8103 -1.0000
0.1657 0.8382 0.4067 -1.0000]

Qxx=[0.2837 -0.0050 0.0242
-0.0050 0.3010 0.0380
0.0242 0.0380 0.2891]

Quu=[0.3020 0.0261 0.0226
0.0261 0.2568 0.0031
0.0226 0.0031 0.3150]

HDOP = 0.748;
PDOP = 0.935;
GDOP = 0.935.

The X,Y,Z coordinates in WGS84 [m] of the station are: s = 1.0e+06 *[4.4723, 0.6016, 4.4923].

It seems that the obtained values of DoPs are ideal because they are smaller than 1.

The GDOP is equal to the PDOP due to computational reasons: the rotation matrix R is (3x3), so we consider the position matrix G (3x3) to find Qxx and then Quu. For this reason we don't have the TDOP.

Now we want to represent these data using the LGEO Software, which means to import the data collected, analyze their quality (standard deviation), make adjustments and export the processed results in different formats like CVS and shape files.

Part 2 – Data processing

EX 1. – RTK survey

Let's start by analyzing briefly the steps of data importation because it's also here when we define some important parameters characterizing our survey.

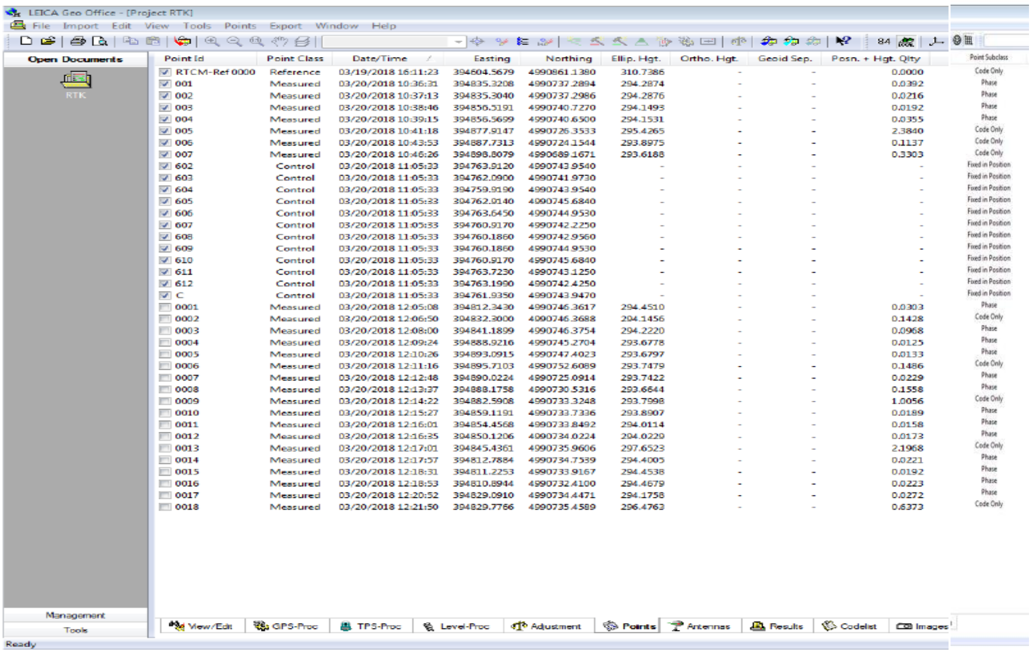
First we create a new coordinate system: describing if geographic, cartographic or other coordinates are used. Then create a new projection to pass from ellipsoid to planar: Italy:32 UTM, north emisphere.

Now it's time to import Smart Worx raw data from folders Team1 and Team2 (Garmin).

The RTCM point is the position of the master station (or eventually of the virtual station) which broadcasts the differential corrections; there can be only 1 virtual station or more, if our area is very huge:

Point Id	Point Class	Date/Time	Easting	Northing	Ellip. Hgt.	Ortho. Hgt.	Geoid Sep.	Posn. + Hgt. Qlty
RTCM-Ref 0000	Reference	03/19/2018 16:11:23	394604.5679	4990861.1380	310.7386	-	-	0.0000
001	Measured	03/20/2018 10:36:31	394835.3208	4990737.2894	294.2874	-	-	0.0392

To analyze the quality (standard deviation) one can look at the last column: it's the horizontal and vertical quality. If we pass to local coordinates, we can appreciate more the quality of the measurements.



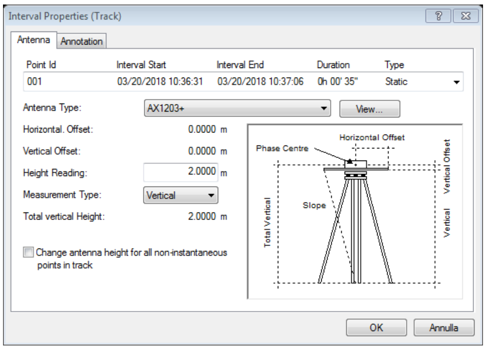
Point Id	Point Class	Date/Time	Easting	Northing	Ellip. Hgt.	Ortho. Hgt.	Geoid Sep.	Posn. + Hgt. Qlty	Point Subclass
RTCM-Ref 0000	Reference	03/19/2018 16:11:23	394604.5679	4990861.1380	310.7386	-	-	0.0000	Code Only
001	Measured	03/20/2018 10:36:31	394835.3208	4990737.2894	294.2874	-	-	0.0392	Phase
002	Measured	03/20/2018 10:37:13	394835.3040	4990737.2986	294.2876	-	-	0.0216	Phase
003	Measured	03/20/2018 10:38:46	394856.5191	4990740.7270	294.1493	-	-	0.0192	Phase
004	Measured	03/20/2018 10:39:15	394856.5699	4990740.6500	294.1531	-	-	0.0355	Phase
005	Measured	03/20/2018 10:41:18	394877.9147	4990726.3533	295.4265	-	-	2.3840	Code Only
006	Measured	03/20/2018 10:43:53	394887.7313	4990724.1544	293.8975	-	-	0.1137	Code Only
007	Measured	03/20/2018 10:46:26	394898.8079	4990689.1671	293.6188	-	-	0.3303	Code Only
602	Control	03/20/2018 11:05:33	394763.9120	4990743.9540	-	-	-	-	Fixed in Position
603	Control	03/20/2018 11:05:33	394762.0900	4990741.9730	-	-	-	-	Fixed in Position
604	Control	03/20/2018 11:05:33	394759.9190	4990743.9540	-	-	-	-	Fixed in Position
605	Control	03/20/2018 11:05:33	394762.9140	4990745.6840	-	-	-	-	Fixed in Position
606	Control	03/20/2018 11:05:33	394763.6450	4990744.9530	-	-	-	-	Fixed in Position
607	Control	03/20/2018 11:05:33	394760.9170	4990742.2250	-	-	-	-	Fixed in Position
608	Control	03/20/2018 11:05:33	394760.1860	4990742.9560	-	-	-	-	Fixed in Position
609	Control	03/20/2018 11:05:33	394760.1860	4990744.9530	-	-	-	-	Fixed in Position
610	Control	03/20/2018 11:05:33	394760.9170	4990745.6840	-	-	-	-	Fixed in Position
611	Control	03/20/2018 11:05:33	394763.7230	4990743.1250	-	-	-	-	Fixed in Position
612	Control	03/20/2018 11:05:33	394763.1990	4990742.4250	-	-	-	-	Fixed in Position
C	Control	03/20/2018 11:05:33	394761.9350	4990743.9470	-	-	-	-	Fixed in Position
0001	Measured	03/20/2018 12:05:08	394812.3430	4990746.3617	294.4510	-	-	0.0303	Phase
0002	Measured	03/20/2018 12:06:50	394832.3000	4990746.3688	294.1456	-	-	0.1428	Code Only
0003	Measured	03/20/2018 12:08:00	394841.1899	4990746.3754	294.2220	-	-	0.0968	Phase
0004	Measured	03/20/2018 12:09:24	394888.9216	4990745.2704	293.6778	-	-	0.0125	Phase
0005	Measured	03/20/2018 12:10:26	394893.0915	4990747.4023	293.6797	-	-	0.0133	Phase
0006	Measured	03/20/2018 12:11:16	394895.7103	4990752.6089	293.7479	-	-	0.1486	Code Only
0007	Measured	03/20/2018 12:12:48	394890.0224	4990725.0914	293.7422	-	-	0.0229	Phase
0008	Measured	03/20/2018 12:13:37	394888.1758	4990730.5316	293.6644	-	-	0.1558	Phase
0009	Measured	03/20/2018 12:14:22	394882.5908	4990733.3248	293.7998	-	-	1.0056	Code Only
0010	Measured	03/20/2018 12:15:27	394859.1191	4990733.7336	293.8907	-	-	0.0189	Phase
0011	Measured	03/20/2018 12:16:01	394854.4568	4990733.8492	294.0114	-	-	0.0158	Phase
0012	Measured	03/20/2018 12:16:35	394850.1206	4990734.0224	294.0229	-	-	0.0173	Phase
0013	Measured	03/20/2018 12:17:01	394845.4361	4990735.9606	297.6523	-	-	2.1968	Code Only
0014	Measured	03/20/2018 12:17:57	394812.7884	4990734.7539	294.4005	-	-	0.0221	Phase
0015	Measured	03/20/2018 12:18:31	394811.2253	4990733.9167	294.4538	-	-	0.0192	Phase
0016	Measured	03/20/2018 12:18:53	394810.8944	4990732.4100	294.4679	-	-	0.0223	Phase
0017	Measured	03/20/2018 12:20:52	394829.0910	4990734.4471	294.1758	-	-	0.0272	Phase
0018	Measured	03/20/2018 12:21:50	394829.7766	4990735.4589	296.4763	-	-	0.6373	Code Only

For some points the quality is about 30-40cm, which means the connection with master station has been lost: we can decide if to accept them or to cancel them from the list.

The points marked as subclass code only have been estimated without phase ambiguity.

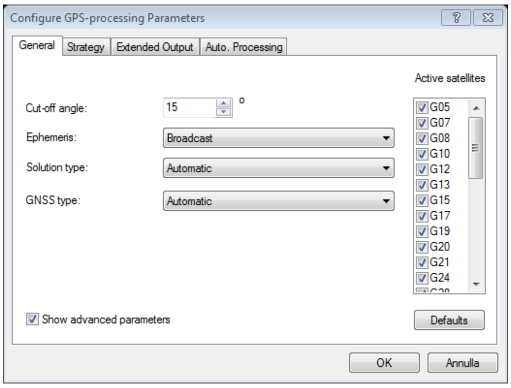
When all the setting has been made, the software displays the baselines between our collected points and RTCM station.

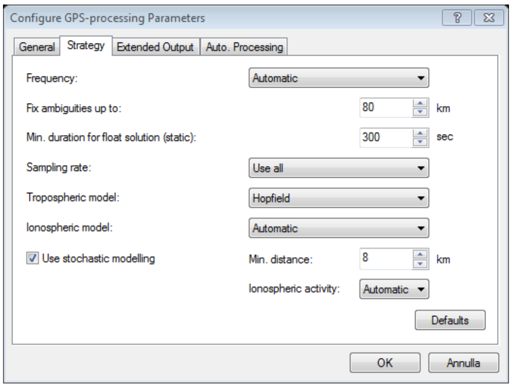
We have to check in the properties of the points also the antenna's height from the ground, which was 2m. If it's wrong, this is usually one of the main errors of data processing because there is no a strategy to remove it (verify the antenna's height always in the field).



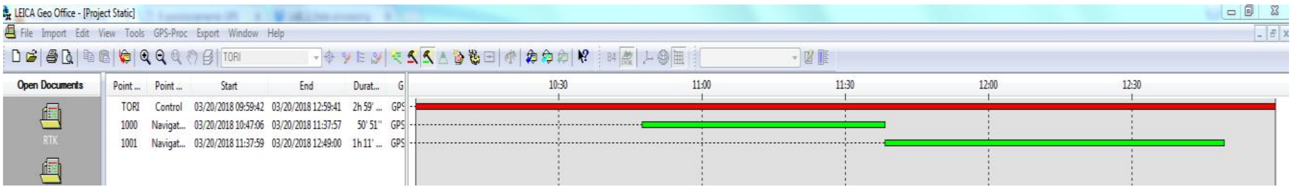
This last points are imposed as "navigated" because are the points estimated by us, instead the can be defined as "estimated" if are estimated by the computer.

We can change also the GPS parameters:

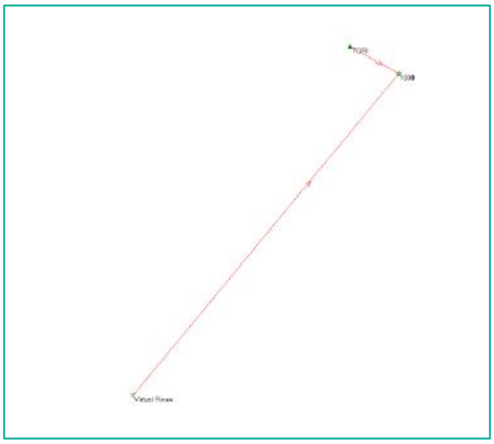




To estimate the 2 baselines we have to set the reference station (where the baseline starts – red line) and the rovers (where baseline ends - green lines).



Verify also if ambiguity is fixed or not, then store the points.



The baselines are created but as we can see the one between Tori and us is more precise because it's closer, instead the virtual station created by the permanent station is too far, so the estimation of the position is less precise. The accuracy is sub-centrimetrical.

Point 1001 is not present because the phase ambiguity has not been estimated.

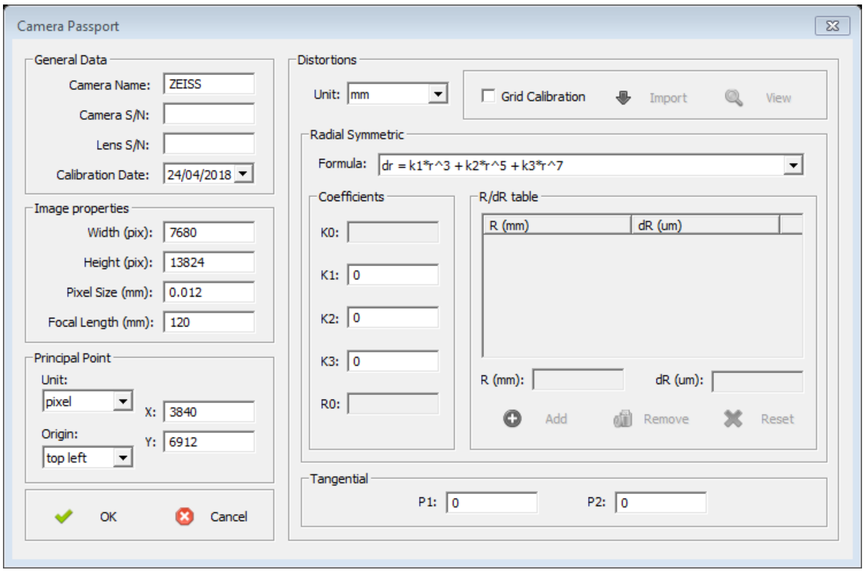
by Loredana Mihaela Chiforeanu

LAB 3 - Photogrammetric stereoplotting

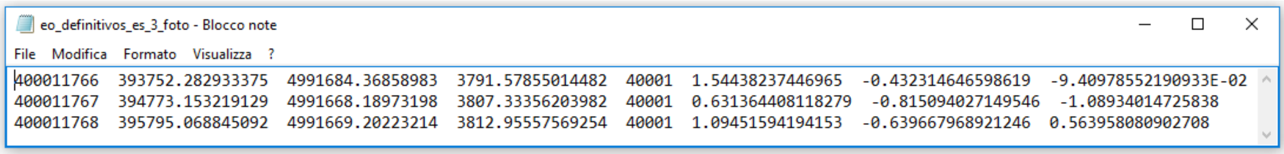
We want to create a 3D model of an area and there are many ways to do so. Here we use the Stereocad software, that generates an anaglyph: it's the name given to the stereoscopic 3D effect achieved by means of encoding each eye's image using filters of different (usually chromatically opposite) colors, typically red and cyan. Anaglyph 3D images contain two differently filtered colored images, one for each eye. When viewed through the "color-coded" anaglyph glasses, each of the two images reaches the eye it's intended for, revealing an integrated stereoscopic image.

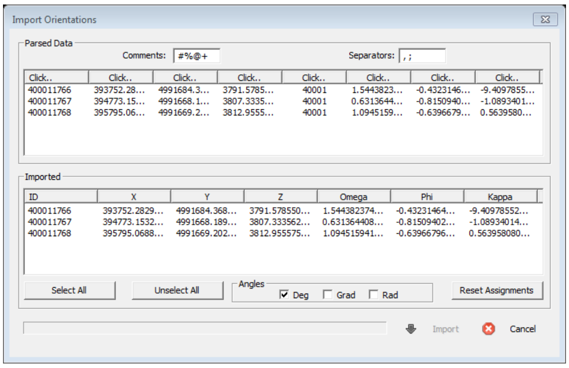
In this laboratory we used also traditional stereoplot instruments to view a 3D model of some areas represented in two aerial photograms, but this operation was very difficult with respect to the use of the software.

In a new project, initially, we have to set at first the camera calibration by determing the internal orientation parameters: position of the principal point with respect to the fiducial center and distance c, which are contained in the Zeiss DMC file; the distortion coefficients are null:



The external orientation parameters are instead contained in a text file, sorted according to the following format: frame number, X, Y, Z translations, strip number, rotations ω, ϕ and k. They must be correctly selected among the columns and named in the software (pay attention of the type of column separator).





Knowing these parameters, we import the image.

by Loredana Mihaela Chiforeanu

LAB 4 - Post-processing of the data acquired in the field

Team 5 A-L-G-J-SP T5(S-5)
Instrument height 1.550m

Part 1 - Field work

On 08/05/2018 we did a field acquisition of points of the facade of the Politecnico's canteen.



We used a Total Station to acquire the coordinates (with respect to our relative position) of 3 points having a prism reflector called 101,102,103. Then, changing the settings of acquisition type to NP (non prism), we acquired natural points belonging to the facade. There were some points marked by us with a paper and other corner points belonging to the facade's elements.

This procedure has been made by other teams for many other points.

Since the prism points 101,102,103 are used to merge all the results from the other teams, we measured them by using the CS (straight) and CD (upside down) sides of the station in order to cancel the systematic errors of collimation, inclination and glass eccentricity.

The natural points have been acquired only with CS to be quick and they may be affected of errors due to laser divergence, not good pointing,….

Far more we used also a drone and an automatic laser to scan the façade and to take pictures.

The drone needs an operator that decides its altitude, camera inclination and snapping position, while the automatic laser station must be placed in such a way to overlap views from both sides of the building.

Part 2 - Office work

Now, the point clouds from all the instruments and teams must be put together, filtered, selected and a final 3D model should be created.

To start let's first open LGeo Software; check that there is the reference system WGS84 32 Nord; create a New Project; import from GNSS_data all the files: select only the one named, because the others are affected by errors due to the duration of some seconds or minutes of the satellite visibility.

We add the coordinates of master station TORI, whose file are in RINEX format:

- 18g: GLONASS navigation file
- 18n: GPS navigation file
- 18o: observation file

As before we declare that TORI is a master station and set the height of the instrument (for all 3 points, otherwise we lose 36 cm of the vertical offset.

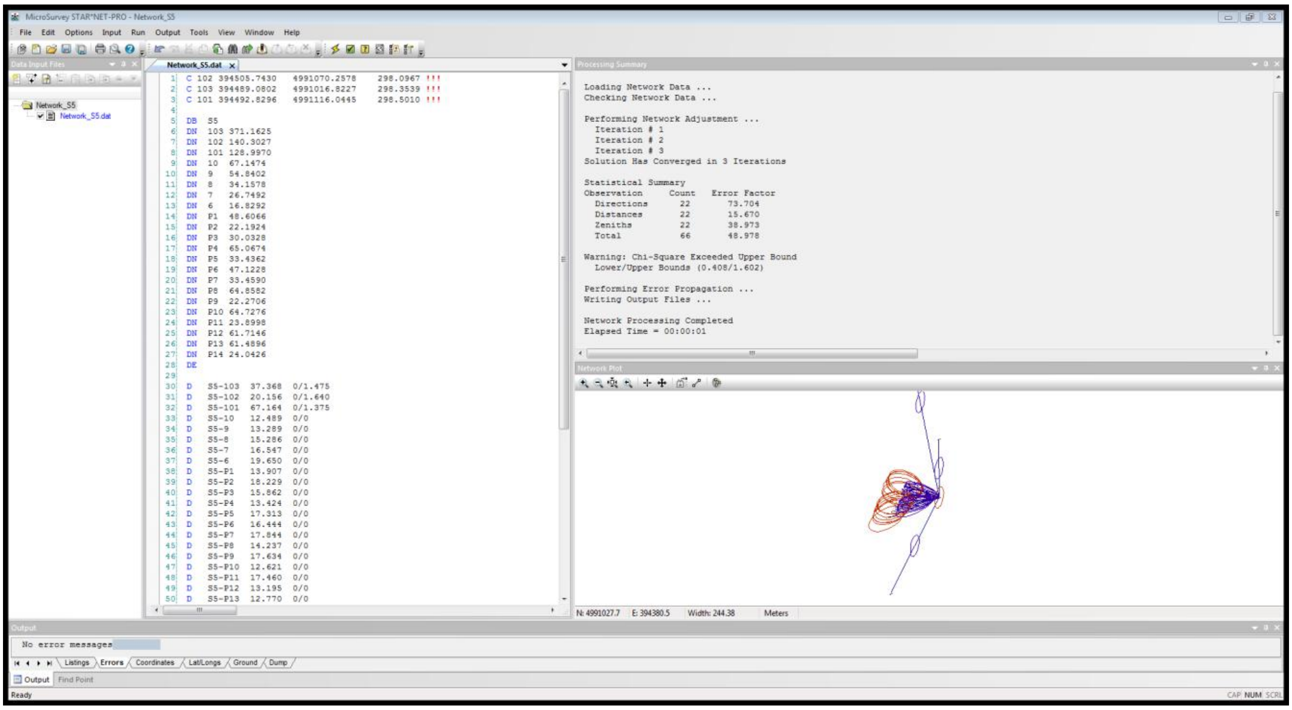
	H_target	**Azimuth**	**Zenith**					
Point ID	**Prism H (m)**	**Horizontal angle (gon)**	**Vertical angle (gon)**	**Distance (m)**	**Average distance (m)**	**Error distance (m)**	**Bessel AZ (gon)**	**Bessel ZEN (gon)**
103-CS	1,475	371,1644	99,9342	37,368	37,3675	0,001	371,1625	99,9482
103-CD	1,475	171,1606	300,0378	37,367				
102-CS	1,640	140,3070	100,2712	20,156	20,156	0	140,3027	100,2754
103-CD	1,640	340,2984	299,7204	20,156				
101-CS	1,375	128,9996	100,2462	67,163	67,164	0,002	128,997	100,2469
101-CD	1,375	328,9944	299,7524	67,165				

Following are reported the coordinates of the points acquired with a total station. Points 6,7,8,9 are markers put on the surface and points P1-P14 are natural points belonging to the surface.

Point ID	Azimuth	Zenith	Distance	h_station	/	h_target
103	371,1625	99,9382	37,368	0	/	1,475
102	140,3027	100,2754	20,156	0	/	1,640
101	128,9970	100,2469	67,164	0	/	1,375
10	67,1474	99,9128	12,489	0	/	0
9	54,8402	97,9834	13,289	0	/	0
8	34,1578	100,3582	15,286	0	/	0
7	26,7492	105,2010	16,547	0	/	0
6	16,8292	99,3964	19,650	0	/	0
P1	48,6066	84,2226	13,907	0	/	0
P2	22,1924	83,5972	18,229	0	/	0
P3	30,0328	101,5778	15,862	0	/	0
P4	65,0674	77,6018	13,424	0	/	0
P5	33,4362	68,5922	17,313	0	/	0
P6	47,1228	61,8728	16,444	0	/	0
P7	33,4590	65,1794	17,844	0	/	0
P8	64,8582	69,4708	14,237	0	/	0
P9	22,2706	105,7858	17,634	0	/	0
P10	64,7276	108,1032	12,621	0	/	0
P11	23,8998	87,8038	17,460	0	/	0
P12	61,7146	83,5920	13,195	0	/	0
P13	61,4896	101,9910	12,770	0	/	0
P14	24,0426	101,4310	17,120	0	/	0

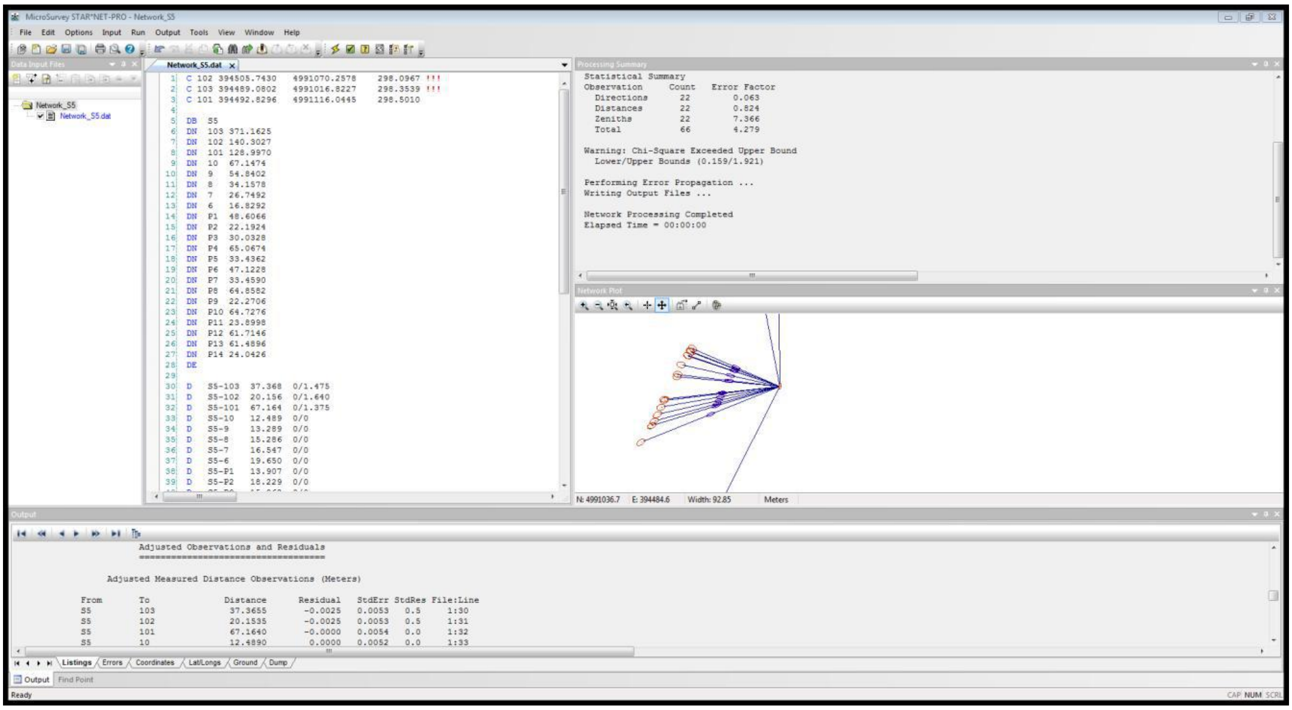
Following there is a sketch of the façade with the location of our points and the sheet that we used together with the total station to record their values

The software shows a statistical summary where we can see that the error factors are huge.



This is due to control point 101, having not fixed phase ambiguity because it didn't connect with the satellite for enough time.

If 101 is not counted in the analysis, the errors are smaller:



But even in this case the total error factor doesn't stay in the boundaries of the Least Square Method test due to big outliers in the Zenith values (listed by the software with an asterix), so if we don't include one of them in the calculations we will pass the test at level of significance 5%.

by Loredana Mihaela Chiforeanu

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LAB 5 – Creation of 3D Models

In this laboratory we will see two different ways to create the 3D model of the facade where we did the survey. On one hand we use the scans collected by the laser, on the other hand we use the photos collected using a drone.

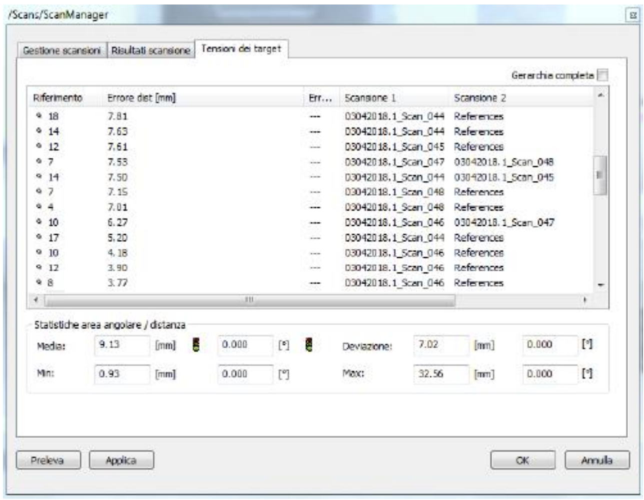
Part 1 - SCENE

In the SCENE software we have to import all the scans, impose the planar view and find the checkerboard points: we eliminate the wrong ones and add the unfounded ones, then we change their names as they were called in the field, as we have done in the previous laboratory.

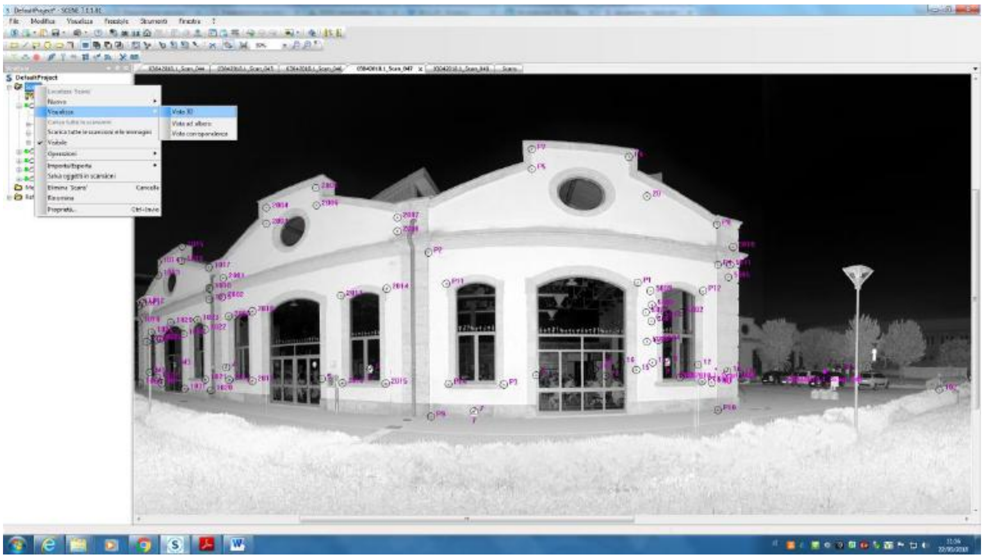
Using Excel we transform the .txt file containing the coordinates of all points (prisms, markers, natural) into a .csv (Comma-separated values) file, correcting the default syntax, in order to have the correct format for understandable by the software.

After importing it, we do the registration based on targets, (markers 1,2,3 are not more available).

In "tensioni dei target" we can see the errors in the measurements of the distance: markers 6,7,8,9,10 are the ones with the best precision and accuracy.

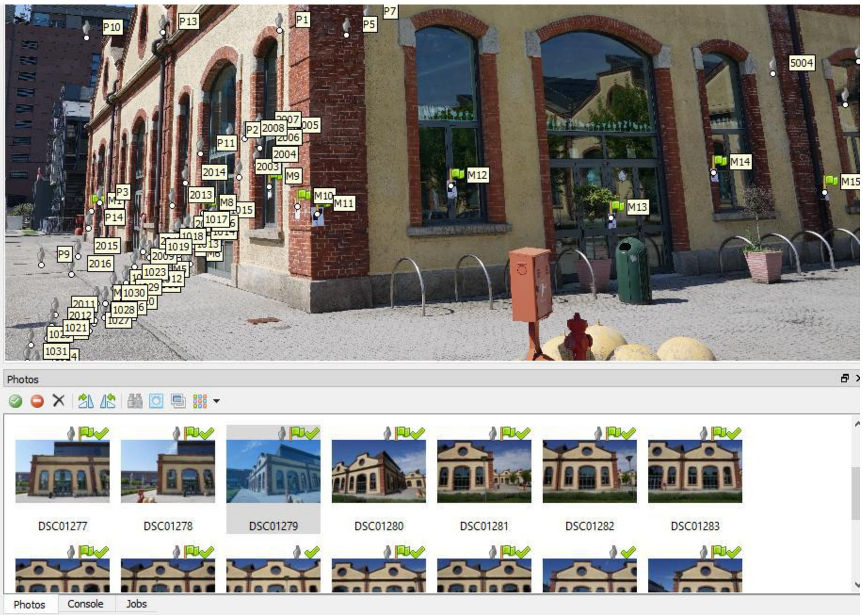


It is possible to see on the point clouds, all the points recorded in the survey by all the teams.



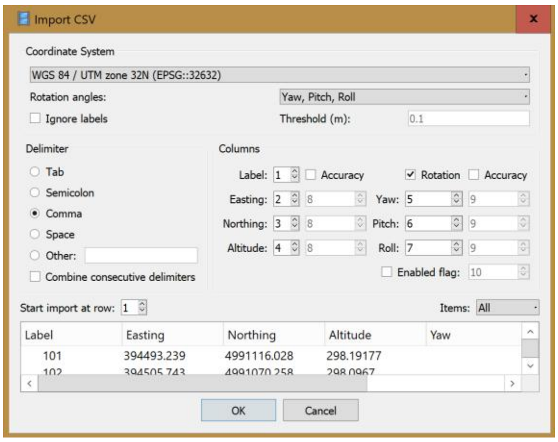
by Loredana Mihaela Chiforeanu

Since we have a normal laptop and the computational load will be too much we select "Low accuracy". But if the similarity is too much maybe the software is not able to detect the single feature.



Images and markers must be in the same chunk, or we can create different chunks for each façade and merge them at the end.

We must identify the markers and the natural points by importing the .csv file (created before) containing the coordinates: select coordinates system WGS84/UTM zone 32N, with rotation angles yaw, pitch, roll, separated by comma, which is the "adaptive camera model fitting" so it estimates the internal orientation of the camera.



We identify the markers and the natural points. In the first image we impose the marker's names: the software will recognize them also in the other images. After that we must "Update" so the natural points do a re-calculation and re-position. Also for better accuracy and lowering the produced errors we need to check the markers being in the place with respect to images and we update points over again.

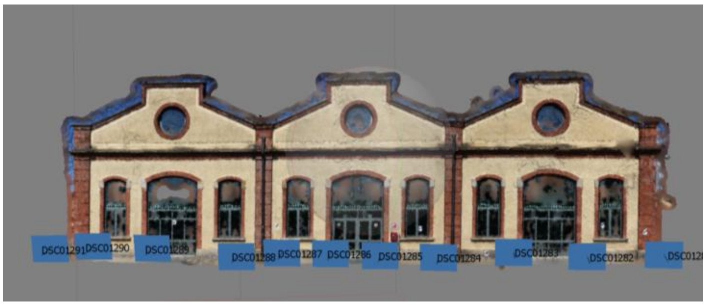
Now we can check errors: the total error is acceptable because it has the same order of the accuracy of the permanent station.

Total Error			
Control points	0.020835	0.012103	0.005189
Check points			

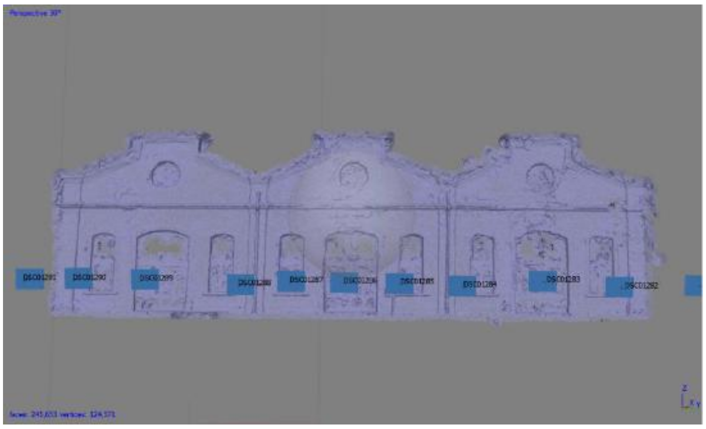
Our total error is about 2 cm which is less than the margin of 10 cm, so our work is acceptable.

Now for camera calibration it is known that the software is able to estimate the internal calibration parameters and calibrate itself. To do this we must first "Optimize Camera" and then when we check the adjustment tab of camera calibration we can see that the calibrated parameters are already applied.

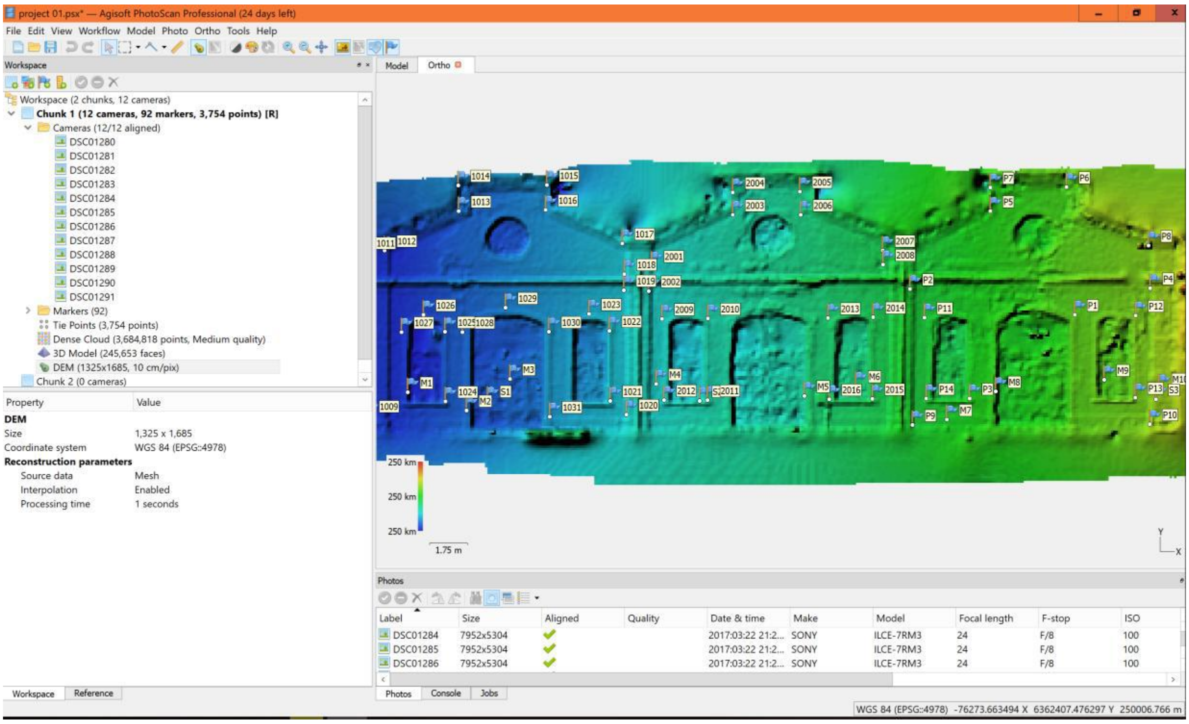
Texture:



Mesh generation:



Depending on the goal of the project it is possible to set the surface type (2,5D or 3D), the input data (preferably the dense point cloud) and the accuracy of the resulting surface (defined in number of faces).



Now that the DTM is created, as mentioned before, it is important to delete the part which is not in our area of interest because their presence will create distractions for the user.

LAB 6 – ArcGIS

The first part of our laboratory is about the learning of the basic techniques that allow us to transform a traditional orthophoto into a digital one using the GIS softwares. Then we will see how to extract the needed information from a database in order to use them to create the model that we need.

Finally we will learn the importance of the output of our work, that will be received by other people who can use it for engeneerical applications.

Part 1

EX 1.

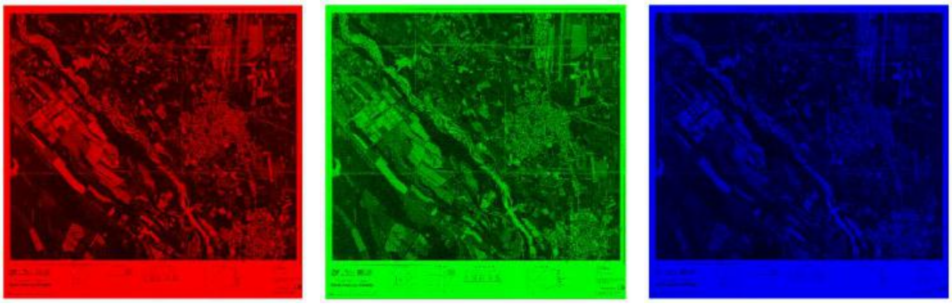
In a traditional map points don't have any info because there is no database, but nowadays it's common practice to work with databases thanks to the use of the computers.

In this exercise we learn how to georeferenced a traditional map.

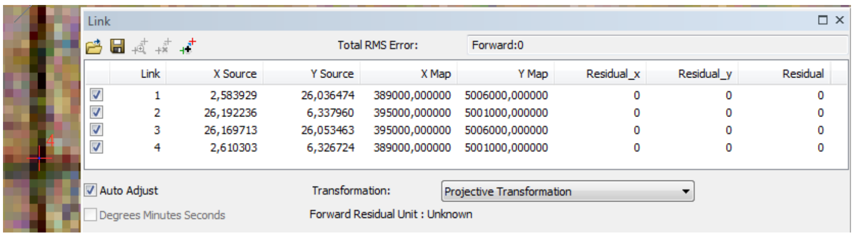
After opening ArcMap software, we need to add the map of Caselle (in .TIFF format) and select the coordinate system: WGS 1984 UTM zone 32N.

Usually as a first operation, the data of interest are loaded, they can be the raster data (the orthophotographic paper) and the vector data (numerical cartography in DWG format). The data can be loaded using the so-called Drag & Drop, that is, clicking on the file of interest and dragging it into the area to the left of the interface, called Layers. So the image, is loaded, (it's a file in TIFF format). It is accompanied by a TFW file, which is a text file containing 6 numbers, corresponding to transformation coefficients to move from pixel coordinates to cartographic coordinates. The software allows us to load only the image file, as it is unable to read the contents of the TFW file already from its name.

The software asked us if we want to create the pyramids of the image:



The map has its grid around which the real coordinates are written, so to report them in the software we need to select several points and input their x and y (x=East, y=North), it is good to have about 4 points located in the four corners of the image so we update the georeferencing. We can see the list of the created points with their coordinates and at the same time evaluate residuals for the different kind of transformations (the unit is [m]):



Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
1	2,583929	26,036474	389000,000000	5006000,000000	0	0	0
2	26,192236	6,337960	395000,000000	5001000,000000	0	0	0
3	26,169713	26,053463	395000,000000	5006000,000000	0	0	0
4	2,610303	6,326724	389000,000000	5001000,000000	0	0	0

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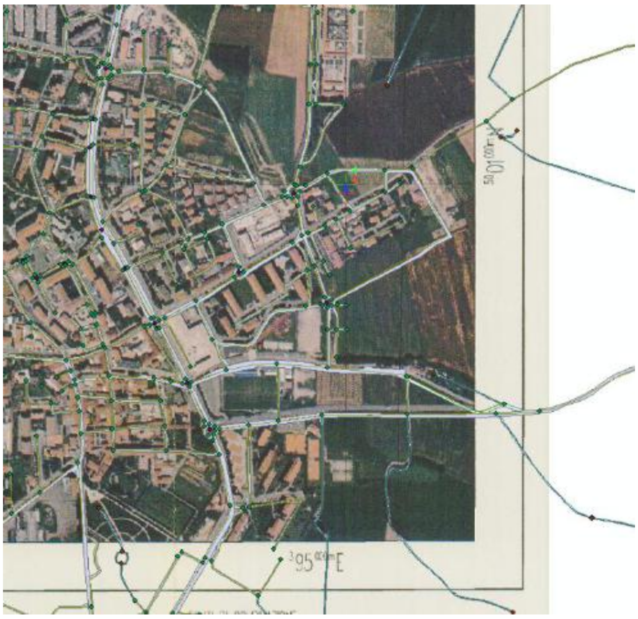


If we verify the residuals we can see that some points/lines/polygons have a good overlapping while others are shifted.

EX 2.

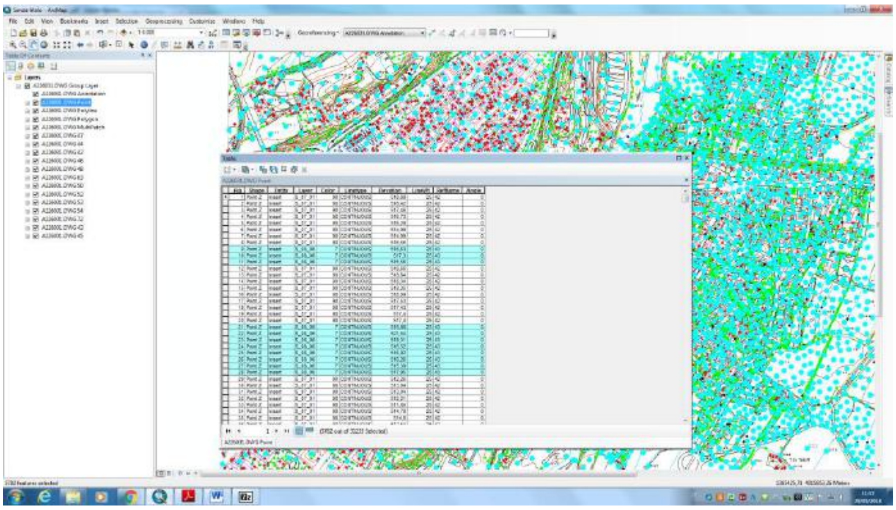
In order to create new smaller databases, i.e. extract only certain characteristics from a big database, we can make a selection by:

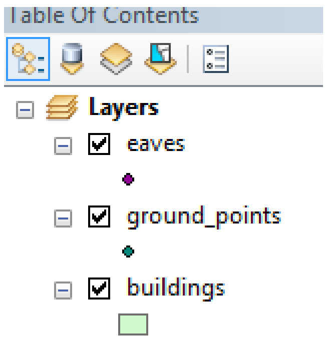
- Attributes: realize a query considering the attributes of the single feature
- Location: realize a query considering the position of the single feature

(Vector data: info is distributed in points, polygons and lines).

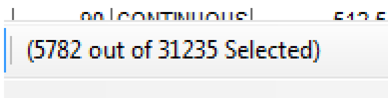
We have to input the .dwg files of Torino area and choose *coordinates, project, national, Italy: Roma Monte Mario Italy 1.* The goal is to create DTM of the city.

Now we can create the selection by attributes: the selected points are shown as cyan (color) points.





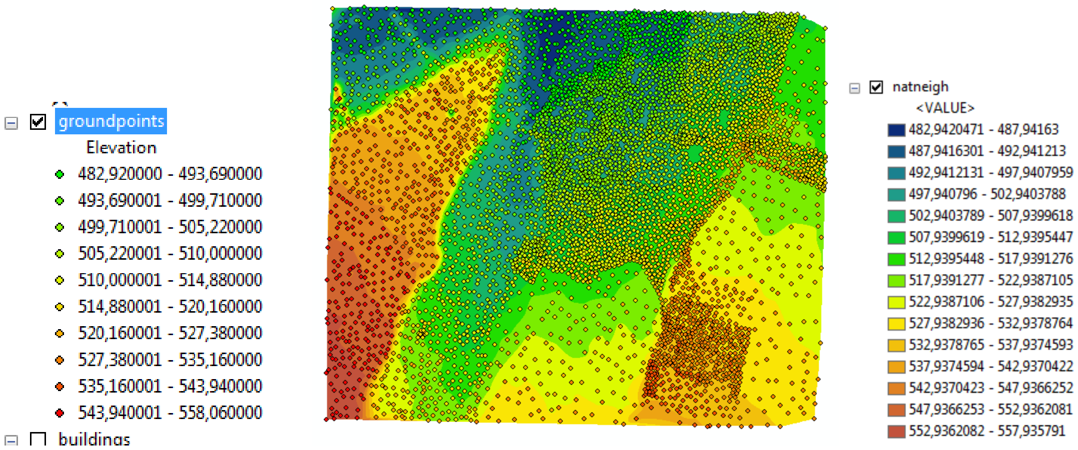
We have selected 5782 ground points, that can be exported as a shape file.



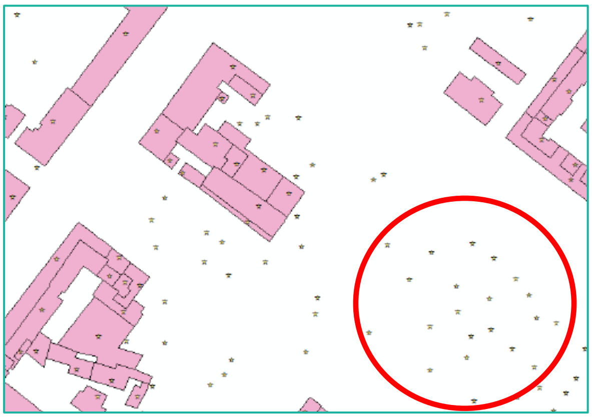
Then we add these three new shape files as layers.

by Loredana Mihaela Chiforeanu

We can impose also that the ground points are classified with respect to their elevation (for a faster reading of the map):



Now we want to join info from the database with the building shapes and the eave points. But we don't want the points that don't belong to buildings:



After applying the command, we obtain a new database having these attributes:

Join_building

Elevation	LineWt	RefName	FID_2	eaves_FID	eaves_Entity	eaves_Layer	eaves_Color	eaves_Linetype	Elevatio_1	eaves_LineWt	eaves_RefN
513,97	25		4	0	Insert	S_08_07	4	CONTINUOUS	517,78	25	45
514,22	25		5	0	Insert	S_08_07	4	CONTINUOUS	517,46	25	45
515,74	25		8	0	Insert	S_08_07	4	CONTINUOUS	519,49	25	45
513,17	25		15	0	Insert	S_08_07	4	CONTINUOUS	518,32	25	45
516,22	25		24	0	Insert	S_08_07	4	CONTINUOUS	523,93	25	45
516,55	25		25	0	Insert	S_08_07	4	CONTINUOUS	525,93	25	45

Now we have two elevations from which we get the buildings' height as : Elev1 - Elev =building's height.

So we create a new attribute table called height, calculate this difference with the field calculator and so get automatically the needed values.

lame	Angle	Distance	height
	0	0	3,81
	0	0	3,24
	0	0	3,75
	0	0	5,15
	0	0	7,71

'Calculate geometry' command is used to calculate areas, perimeters, volumes, coordinates of centroids,…, let's calculate the buildings' area [m^2] and perimeter [m] and volume [m^3] (as area*height) and add them to the attribute table:

Distance	height	area
0	3,81	85,4336
0	3,24	76,6367
0	3,75	63,3592

gth	Shape_Area	height	area	volume	perimeter
4467	85,4336	3,81	85,433	44235,809	37,514
0023	76,6367	3,24	76,636	39656,426	36,03
4055	63,3592	3,75	63,359	32914,470	31,884
7213	215,7899	5,15	215,78	111848,22	70,937
0664	227,0886	7,71	227,08	118978,53	62,601
5403	196,2665	9,38	196,26	103222,44	56,196

Now we can extract buildings with characterized only by certain values of area, or volume, by doing a selection of attributes (as before).

We save and export our project (export data) as a shape file.

by Loredana Mihaela Chiforeanu

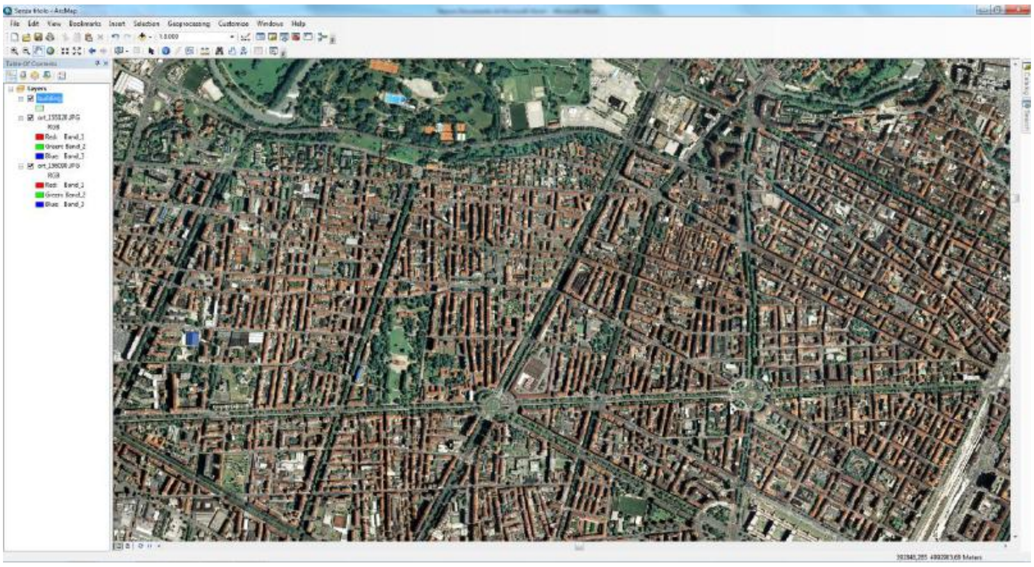
Part 2

The goal of this exercise is to learn how to create new entities, such as buildings, roads, etc…, starting from an orthophoto. We will see that it is possible to use also opendata sources.

We can also extract different kinds of maps, such as aspect maps, slope maps, contour maps.

EX 1.

After importing the given orthophoto in ArcMap, we have the following window. We have to set also the project's coordinate system WGS84-32N and set the units to meters.

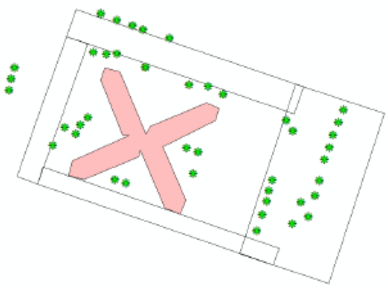


We want to create a database about buildings having as geometry the polygons (ex. The correspondence object-geometry usually is: roads-lines, trees-points). For this reason we create a new feature class: in the settings we add also the Z component so we'll be able to make a 3D model.

We must define the list of attributes so we can add the properties; this list can be managed also later but the geometry will be fixed as polygons. Then if we open the attributes table it's empty because we have to fill it; we can add or remove fields.

We have to select start editing in order to change the database (be careful to avoid mistakes from now).

In *construction tools* we select polygons and try to create by drawing the shape of the buildings. The created objects are put in the attributes tables where we can add info. If we repeat the procedure to create the layers of trees and roads, we get:



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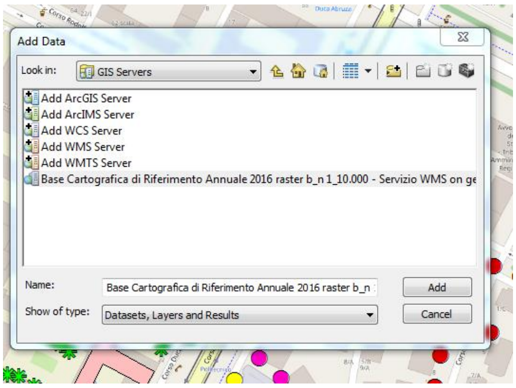
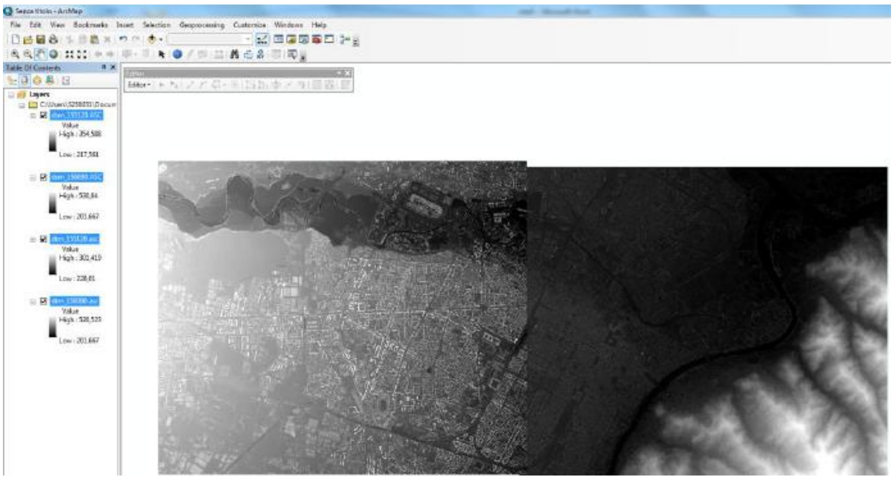
Far more we can use an GIS Server (in *add data*) to import data from a web service. But this needs a very good internet connection because everytime we change visualization, the software downloads data from the server that must be stable.

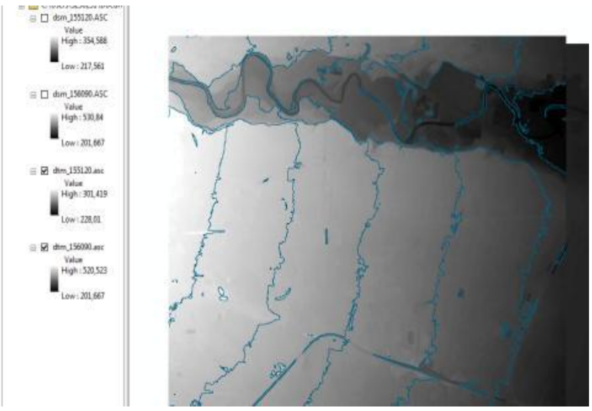


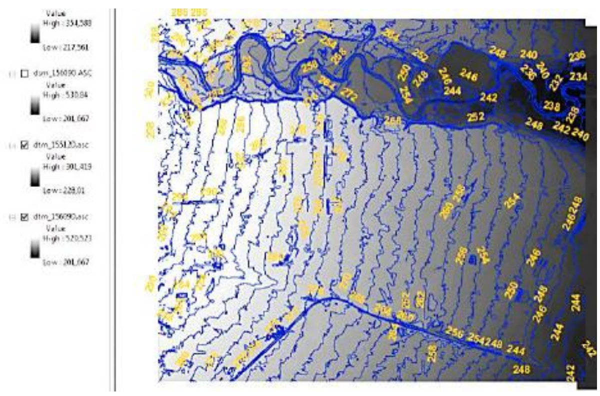
EX 4.

Now let's create a new project, from which we will get different kind of maps: aspect, contour, slope.
So we import the DTM and DSM from GIS folder (maintain only dtm) and impose the coordinates system.



Using the tools we can create the contour map with an interval of 5- 10m. Z factor amplifies elevation. But 10m is too much so let's use 2m to have more contour lines. We can display the values of the lines from the labels property.





Far more we can generate a map where each single pixel represents the slope of the terrain → slope map.
In symbology property we can change again colors for a faster understanding

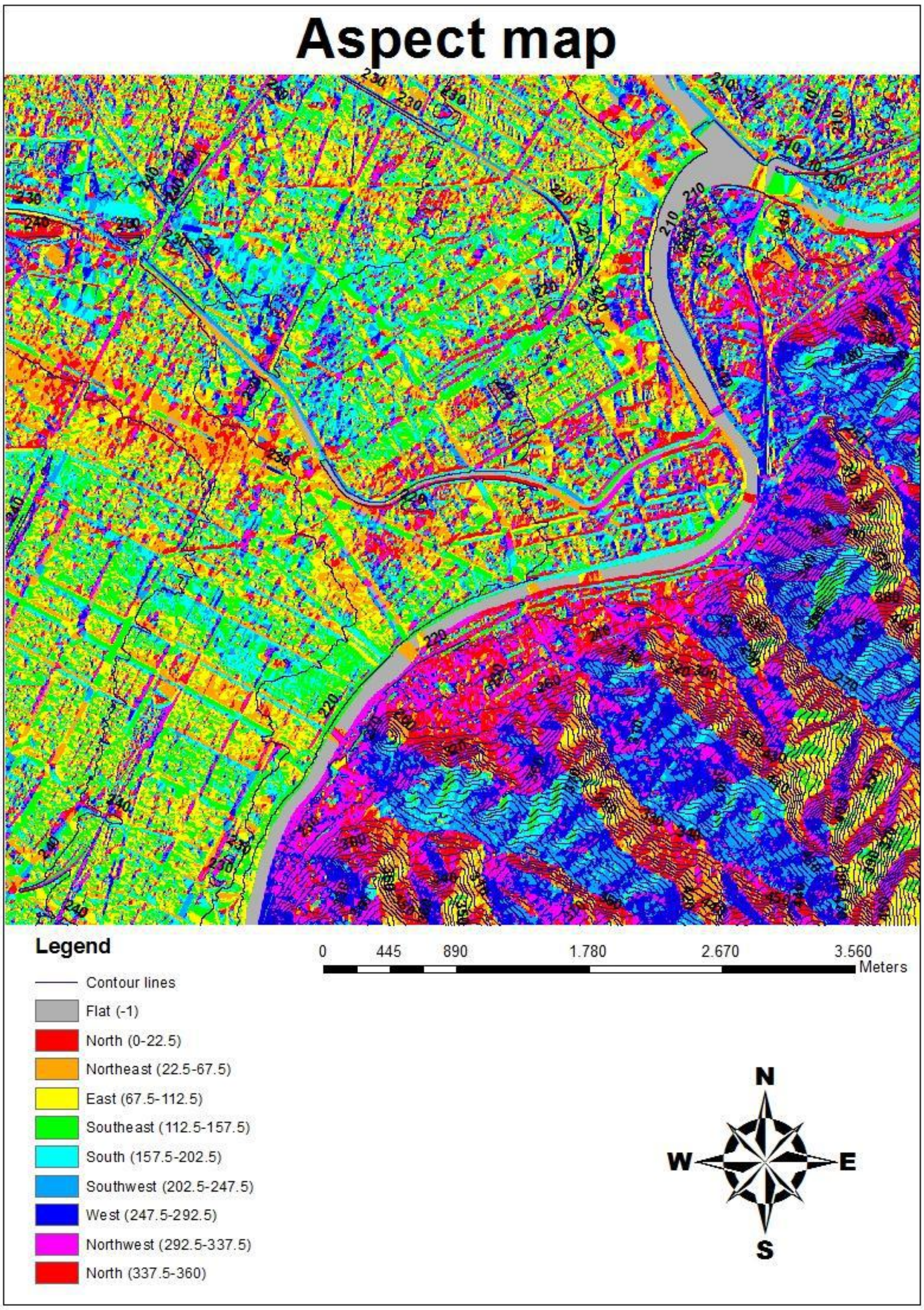
EX 5.

Also the printing of our file is an important operation. First we have to create a lawet for printing.
There are 3 fundamental elements that must be contained in a printed map:

- Legend (meaning)
- North direction (geographical info)
- Scale bar (geometrical info)

We usually use a nominal scale.

Then we can insert the legend with the meaning of the colors and include the icons of the north direction and also the scale bar (very important).
Finally we save the file by export the map, as a pdf file/jpeg.



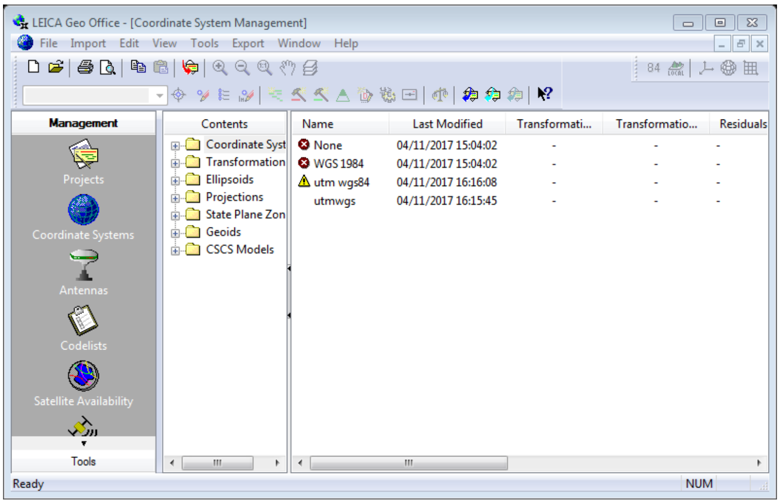
ATTACHMENTS: exercises STEP by STEP

Lab 2 - GNSS data processing

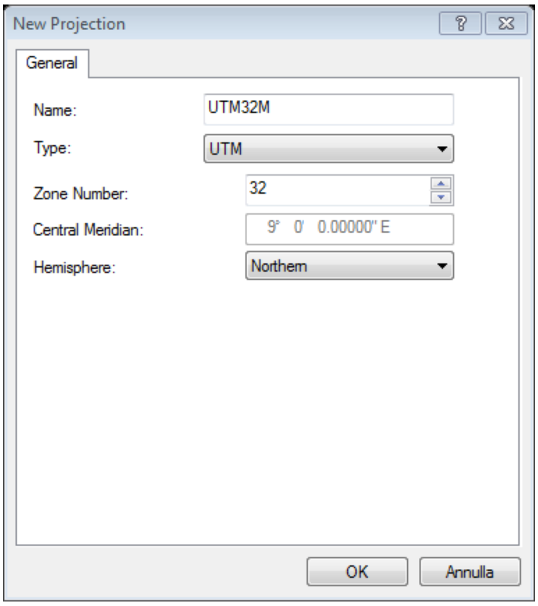
EX 1. – RTK survey

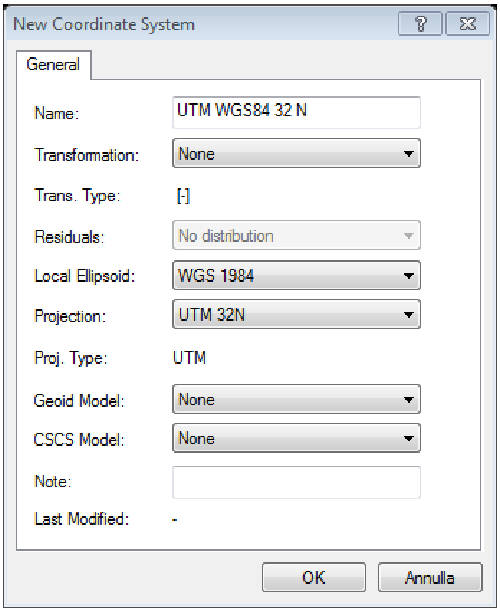
Let's start by analyzing briefly the steps of data importation because it's also here when we define some important parameters characterizing our survey.

First we have to create a new coordinate system (not reference system): describing if geographic, cartographic,… coordinates are used: open Coordinate System tab:

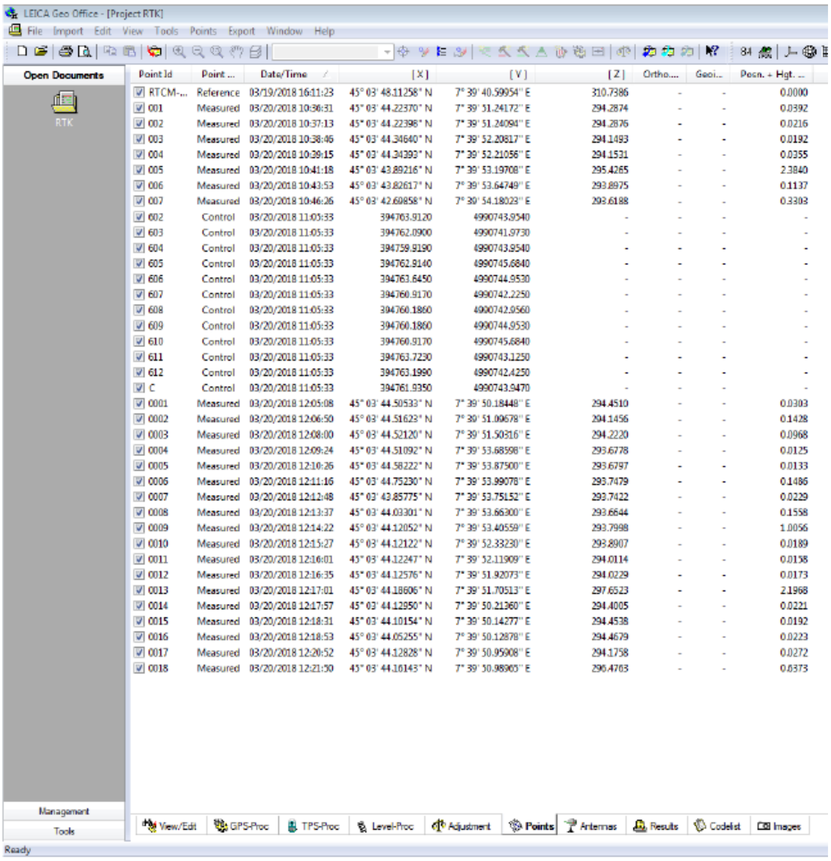


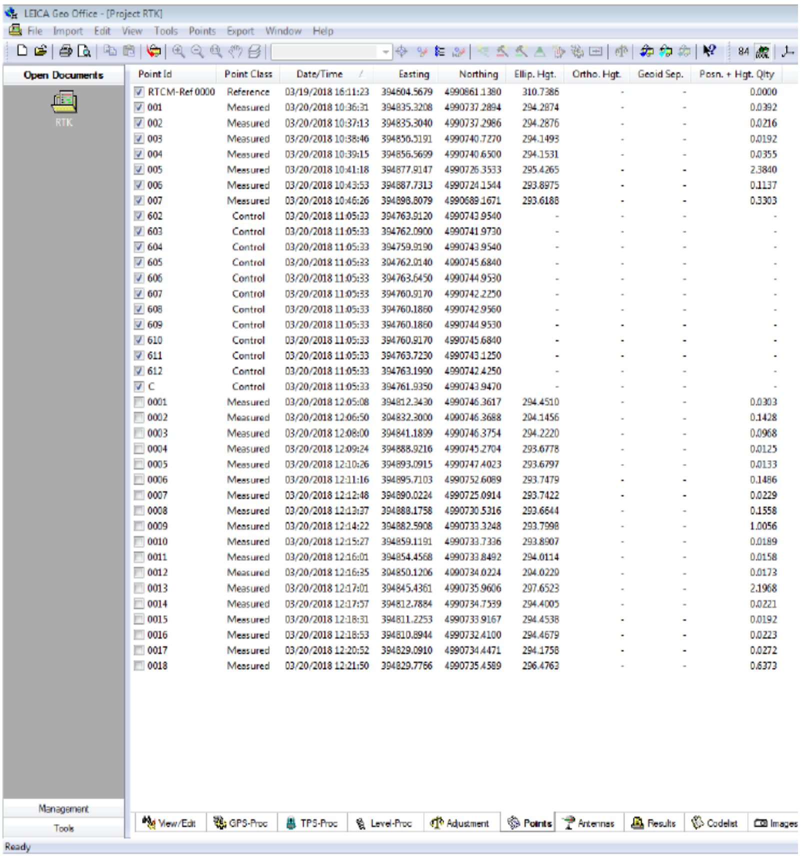
In folder Projections, create a new projection (to pass from ellipsoid to planar): Italy:32 UTM, north emisphere. Also create a new coord specific system in the homonymous folder:



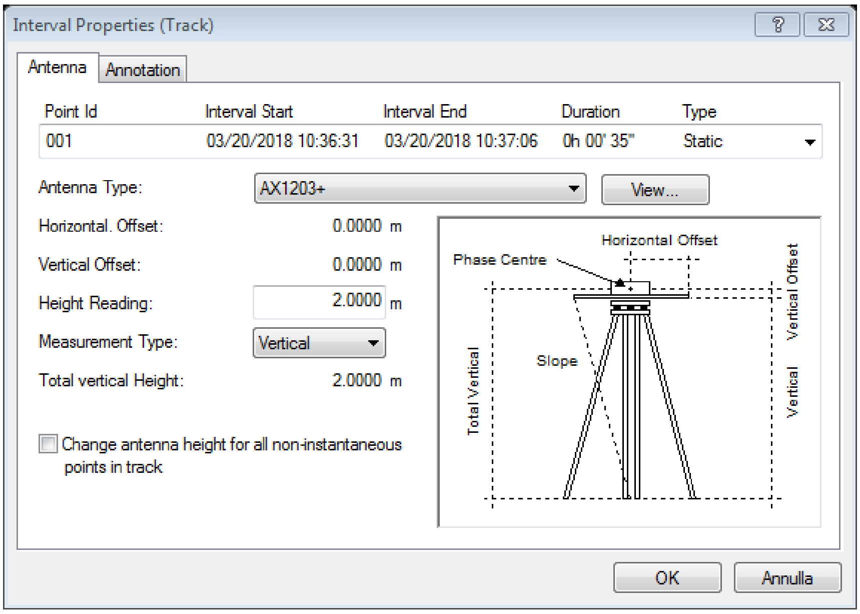


The new project has been saved in local disk D:. Now select to use the coord. Syst. previously created.

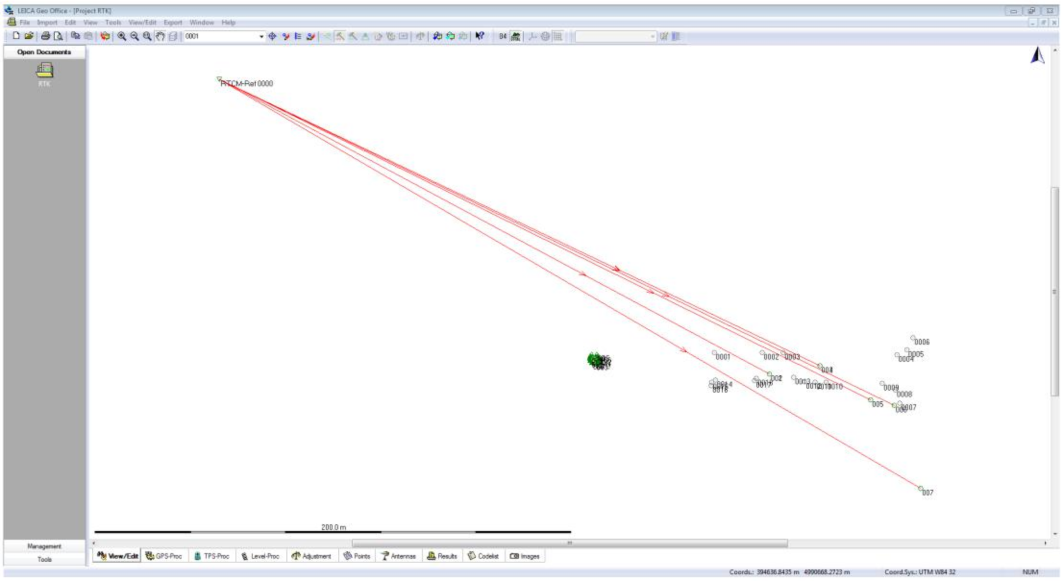




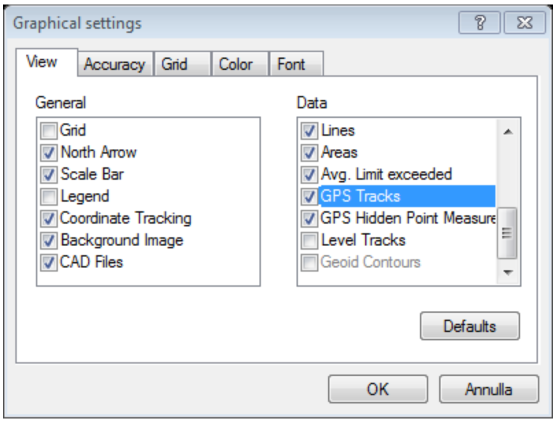
The quality is about 30-40cm, which means that the connection with master station has been lost: we can decide if to accept it or to cancel it.

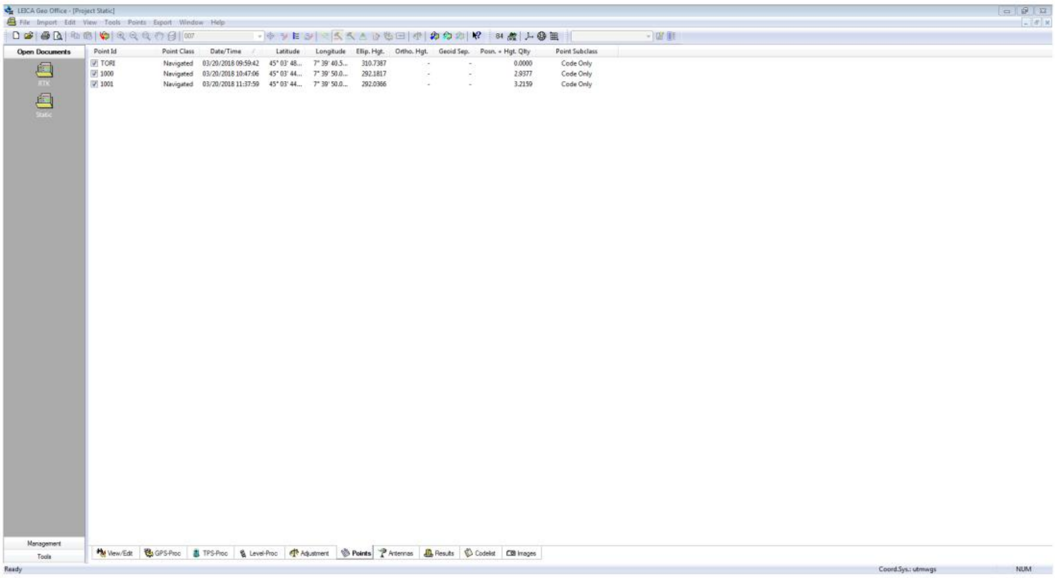


When all the setting has been made the software displays the baselines between collected points and virtual station:

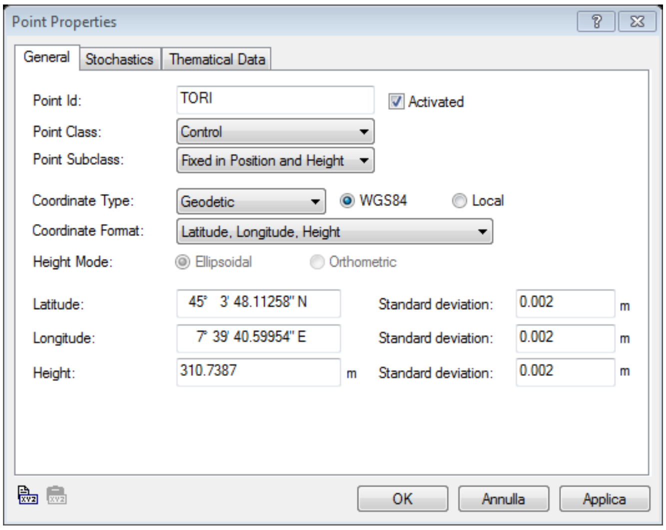


To see our trajectory in the collection of points, click GPS Track in Graphical Settings:

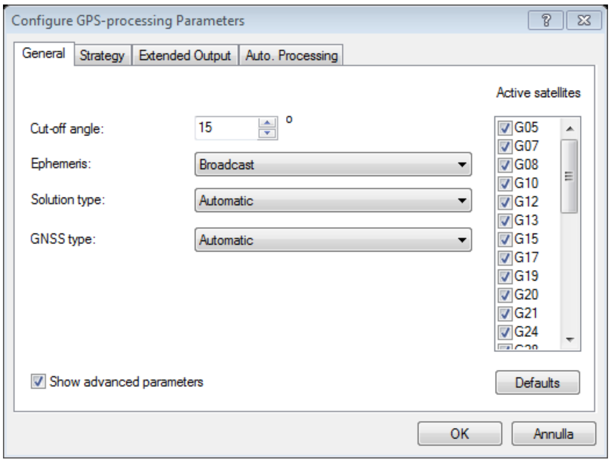


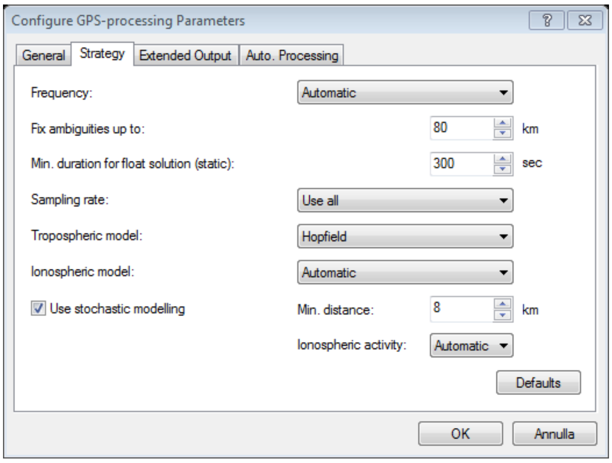


We have to set the parameters: change TORI into control point in order to modify the std. deviation:



We can change also the GPS parameters:





To estimate the 2 baselines we have to select:

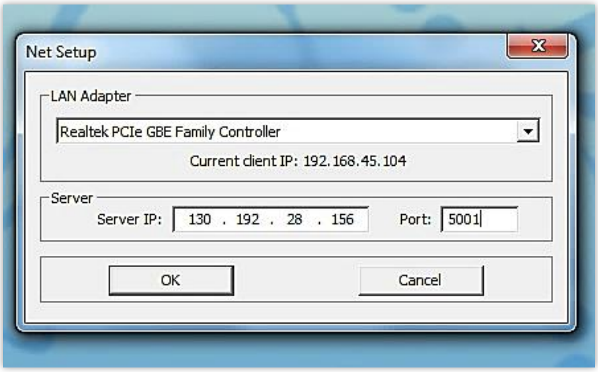
Red hammer=reference station: where the baseline starts.

Green hammer: ref rover where baseline ends.

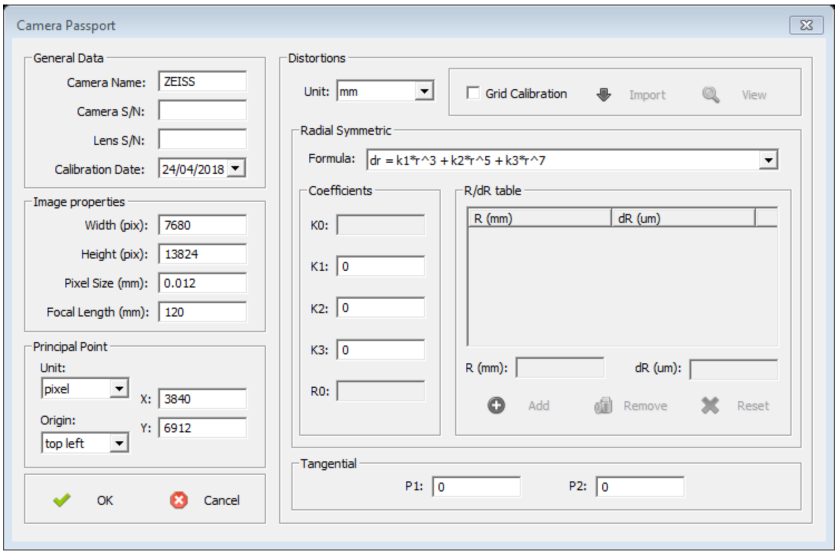
by Loredana Mihaela Chiforeanu

Lab 3 - StereoCAD

Open the software:



Orientations, new: using data from *Zeiss_DMC_Regione_PIEMONTE (wordpad):*



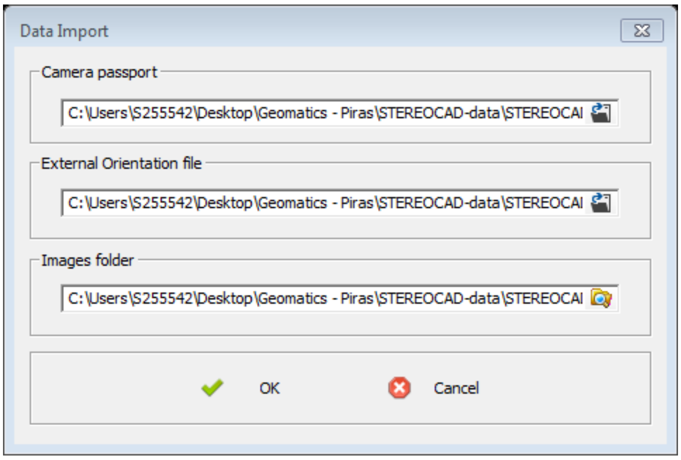
Save as ***.bcc.***

Import the image: *main, import, import generic* :

-*Zeiss_DMC_Regione_PIEMONTE*

-*eo_definitivos_es_3_foto*

-folder that contains images



Do the passing: define the meaning of the single column in the orientation file.

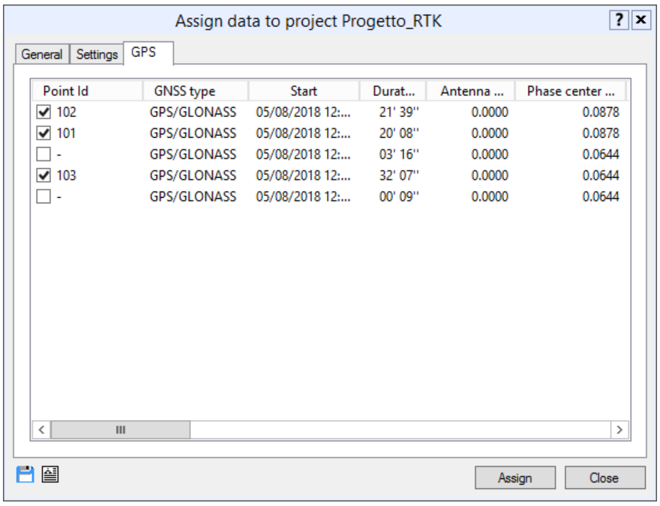
FROM:

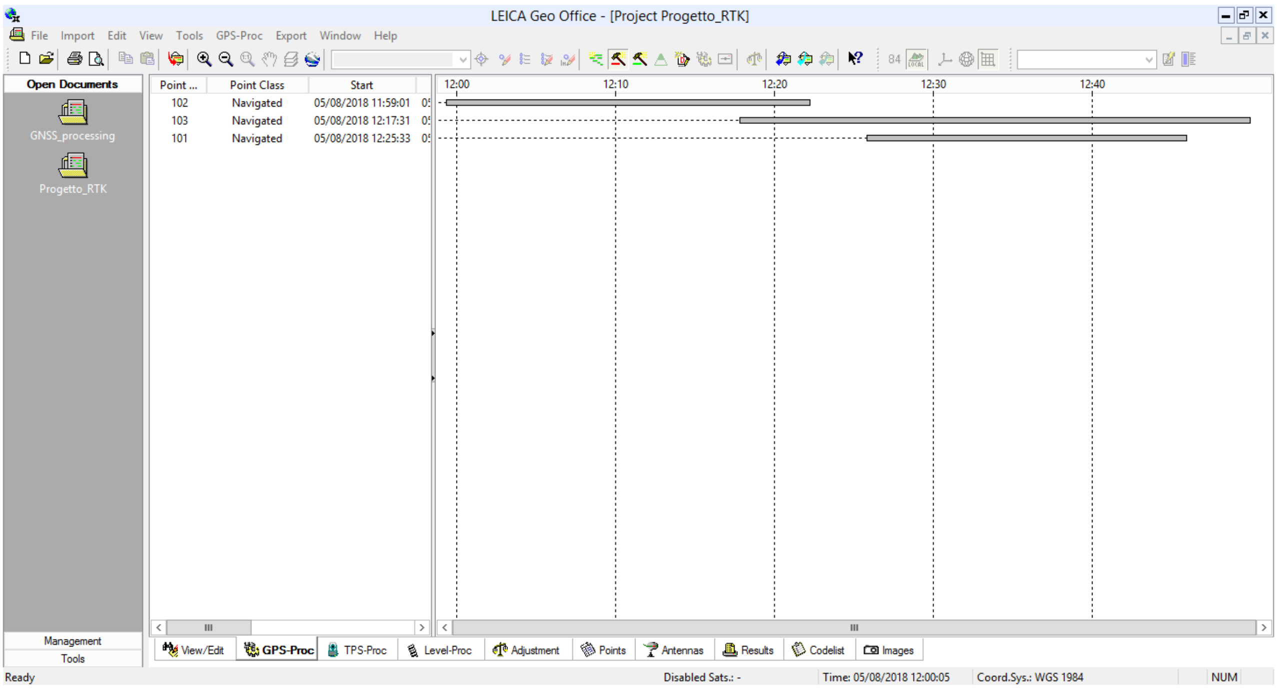
The Level of details depends on the scale factor of the map.

Here we can see that there are two equal images: one blue and one red. In order to know the points' exact coord. we have to perfectly overlap the 2 images (we have to do this for each point). Far more we can draw lines, create layers, measure distance,…, and so we can create a map.

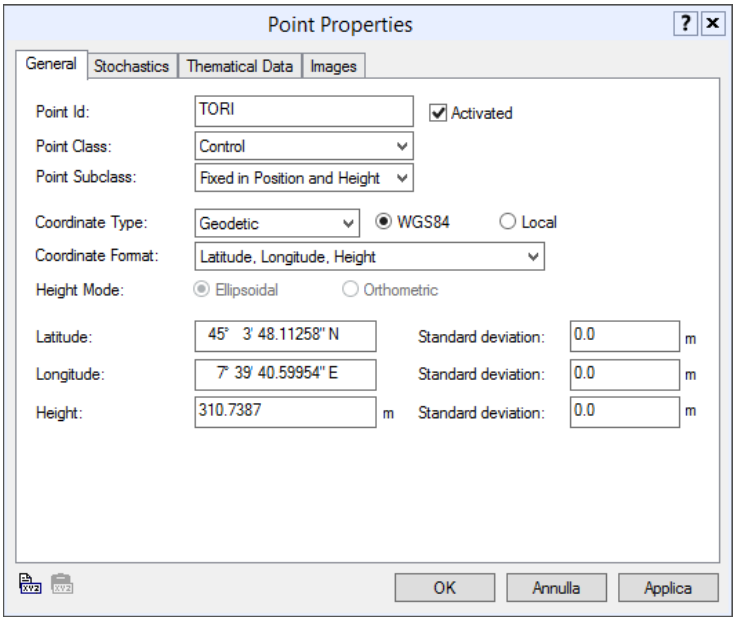
Lab 4 - Post-processing of our acquired data

To start let's first open LGeo Software; check that there is the reference system WGS84 32 Nord; create a New Project and select it; import from GNSS_data all the files: select only these, because the others are too small: duration of some seconds or minutes.

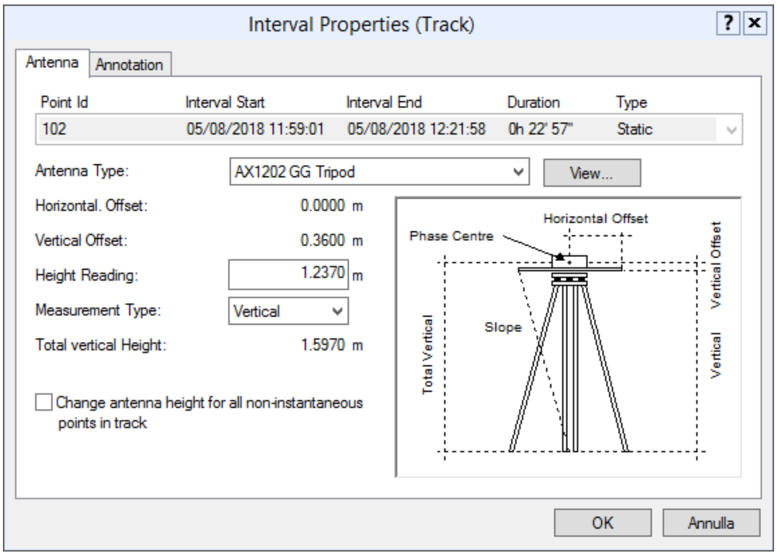




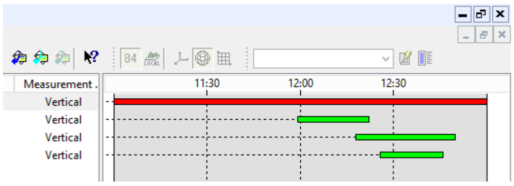
Need to add the master station TORI from the homonymous folder:



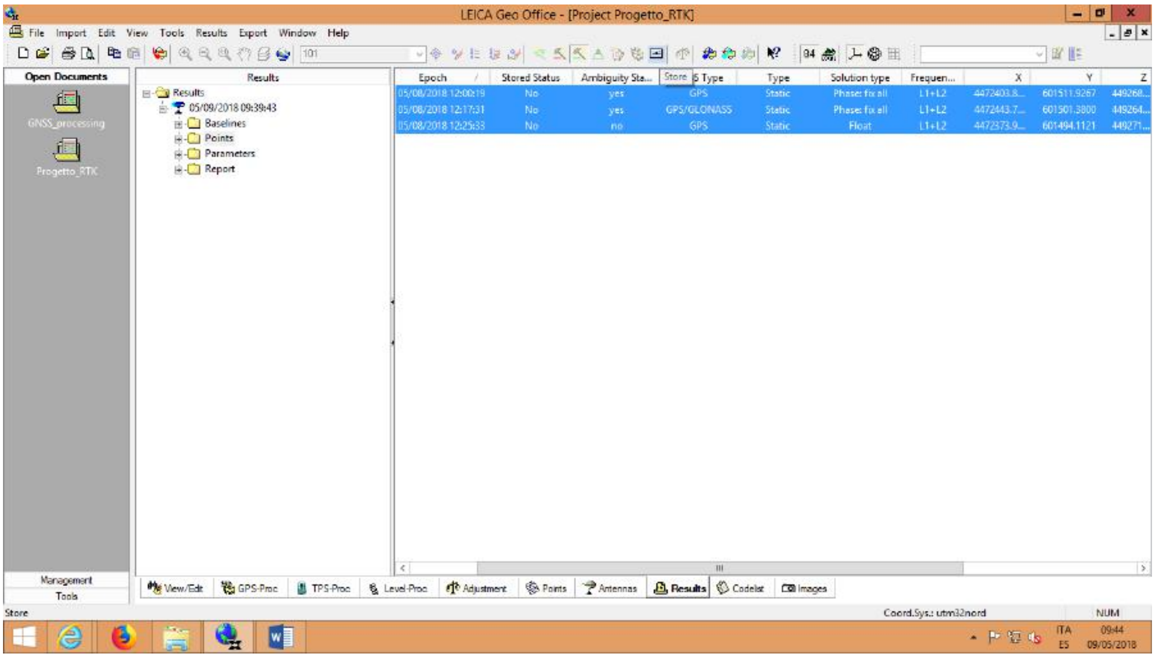
Set the height of the instrument (for all 3 points): select point : properties: antenna on tripod (otherwise we loose 36 cm of the vertical offset).



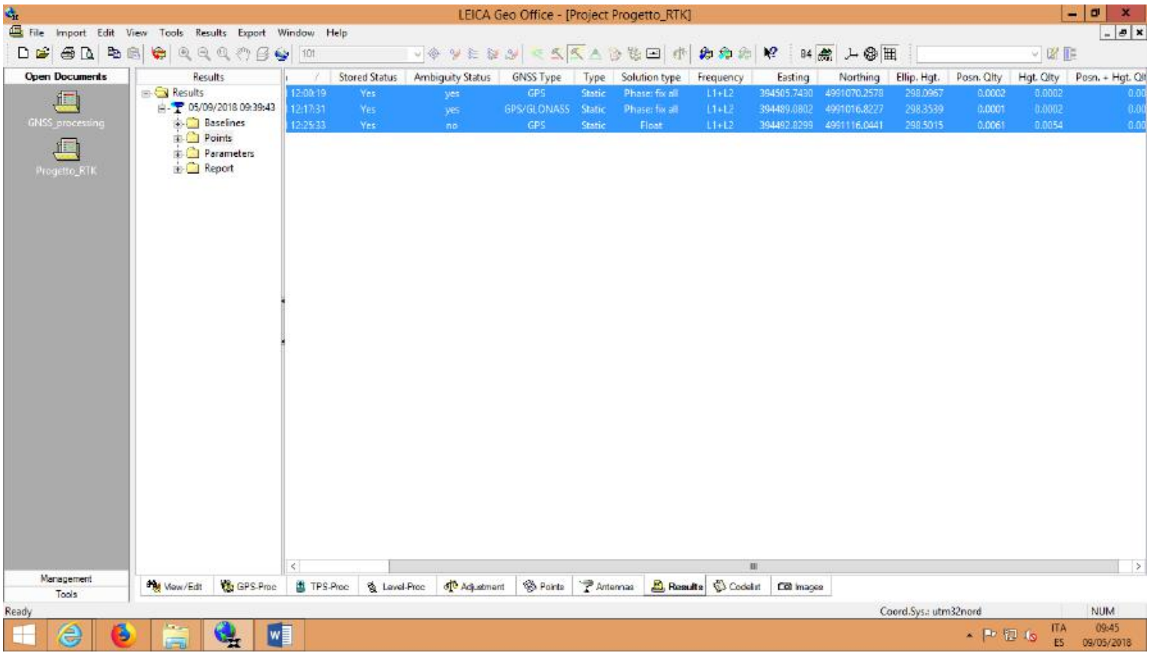
Set with the hammer (=color) master (red) and rover (green):



Click PROCESS: the Results page opens.

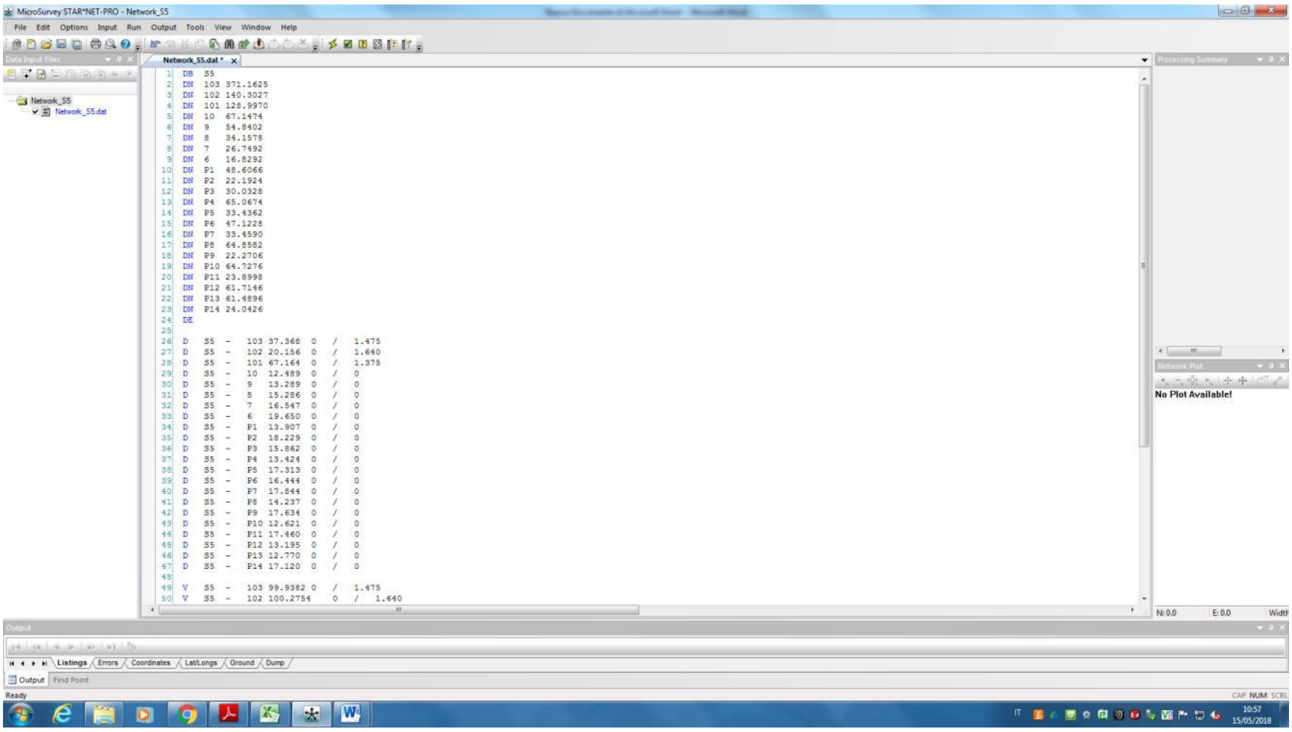


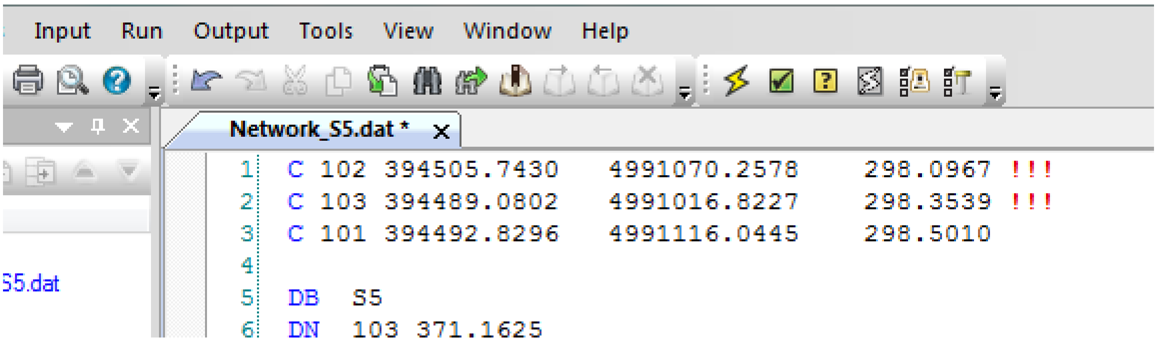
Click local + grid, so we are now in local coordinates where we can overlook the ambiguity :



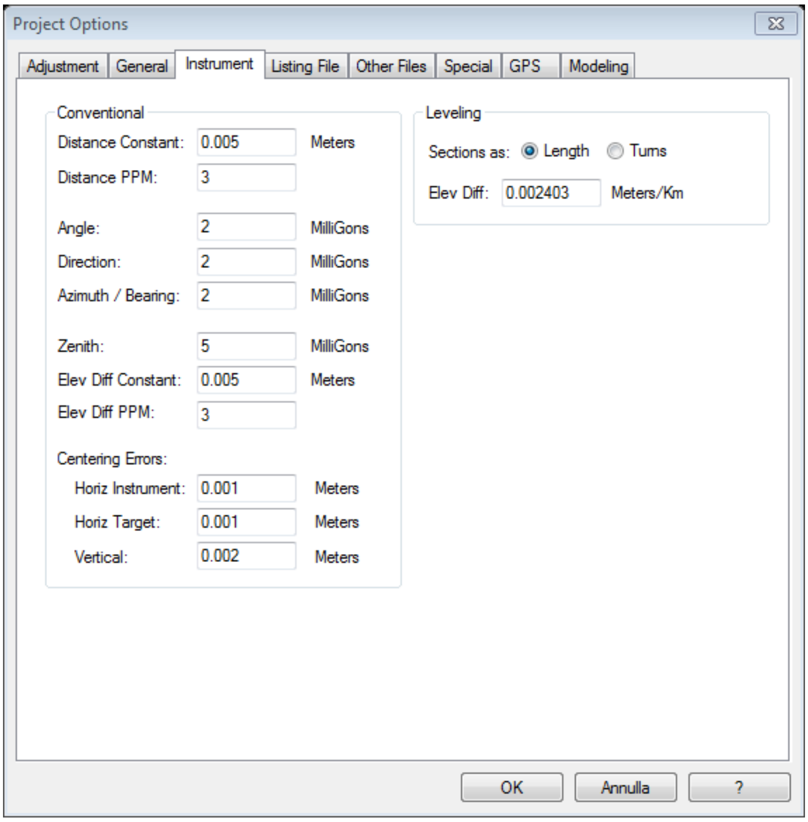
Save as…

Open MicroSurvey StarNet V7 Software:

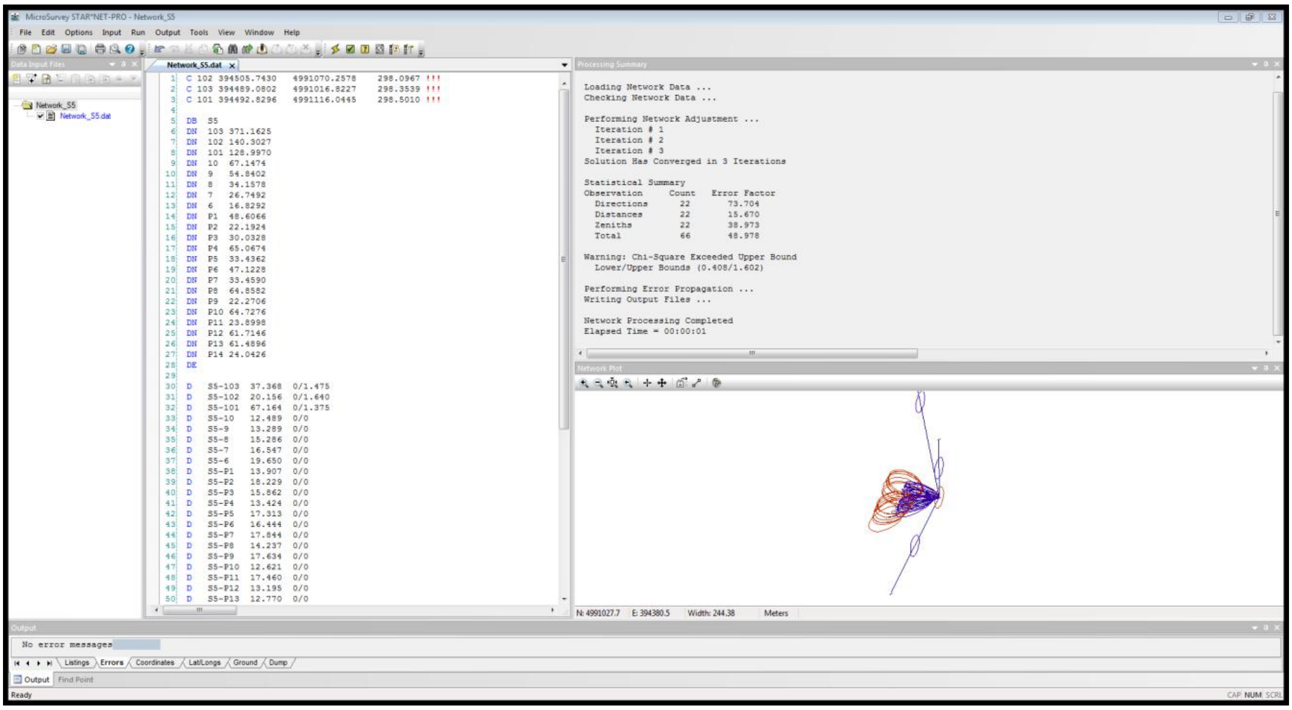




Select: option, project…:

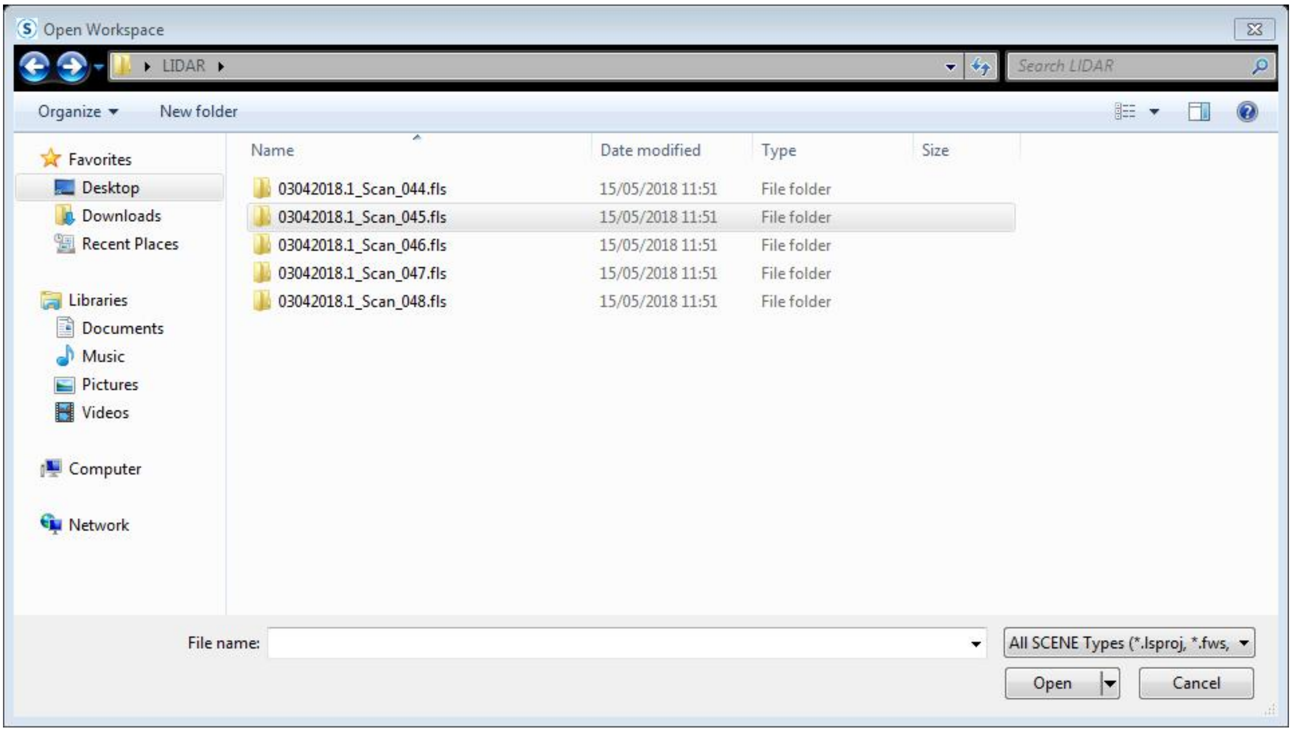


Click ok. Click run.

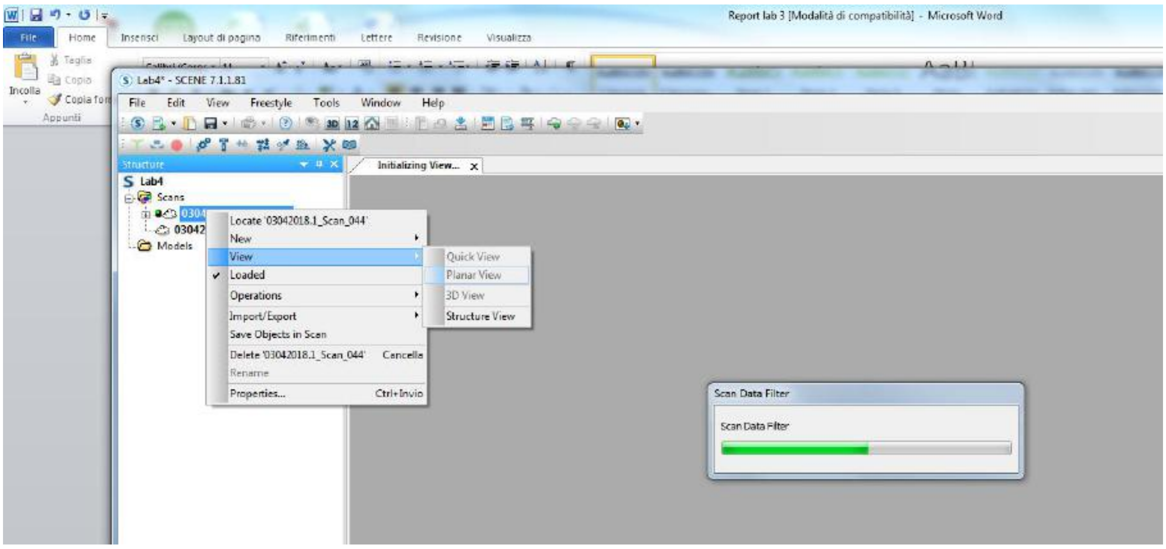


If 101 is not fixed, the errors are smaller because the phase ambiguity is not fixed because it didn’t connect with the satellite for enough time:

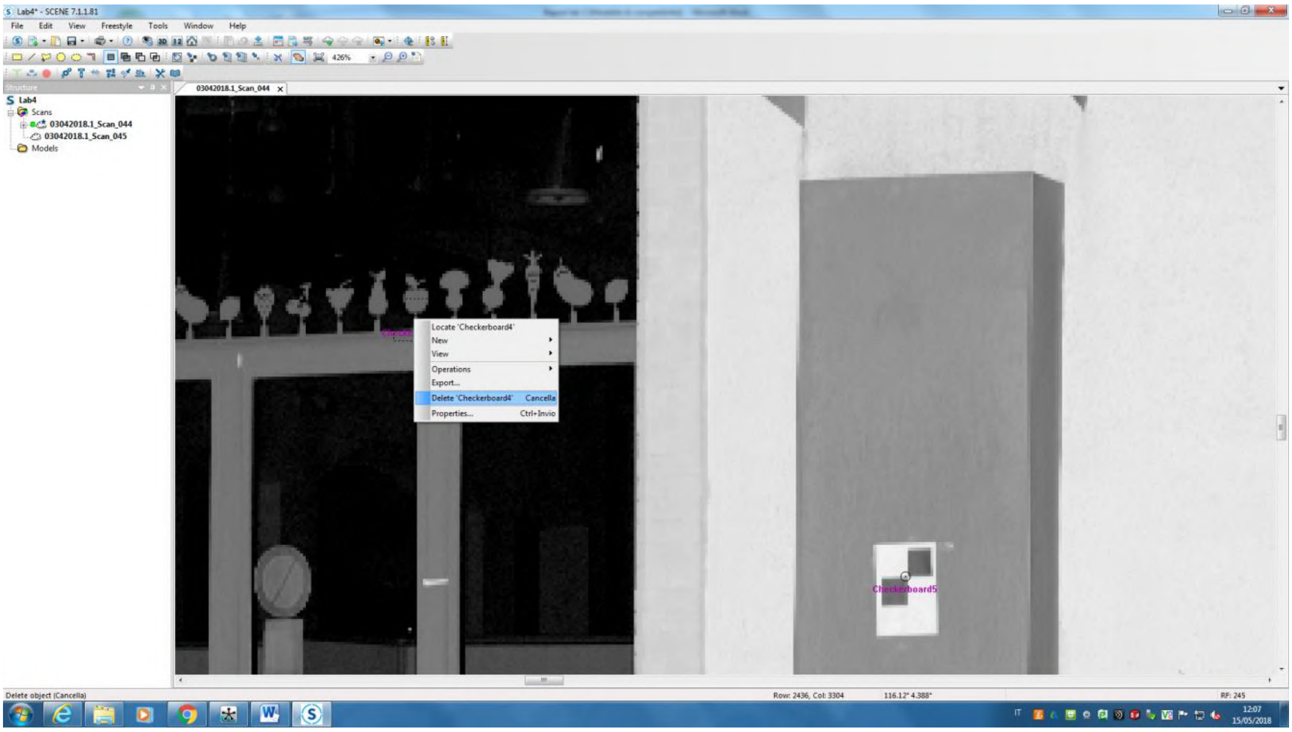
by Loredana Mihaela Chiforeanu

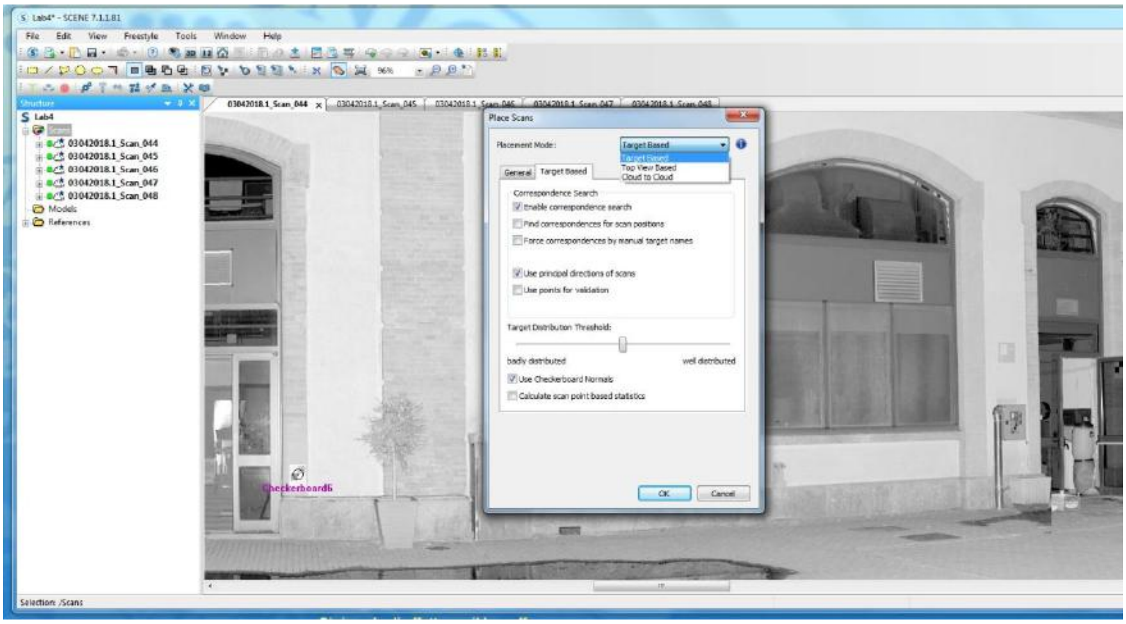


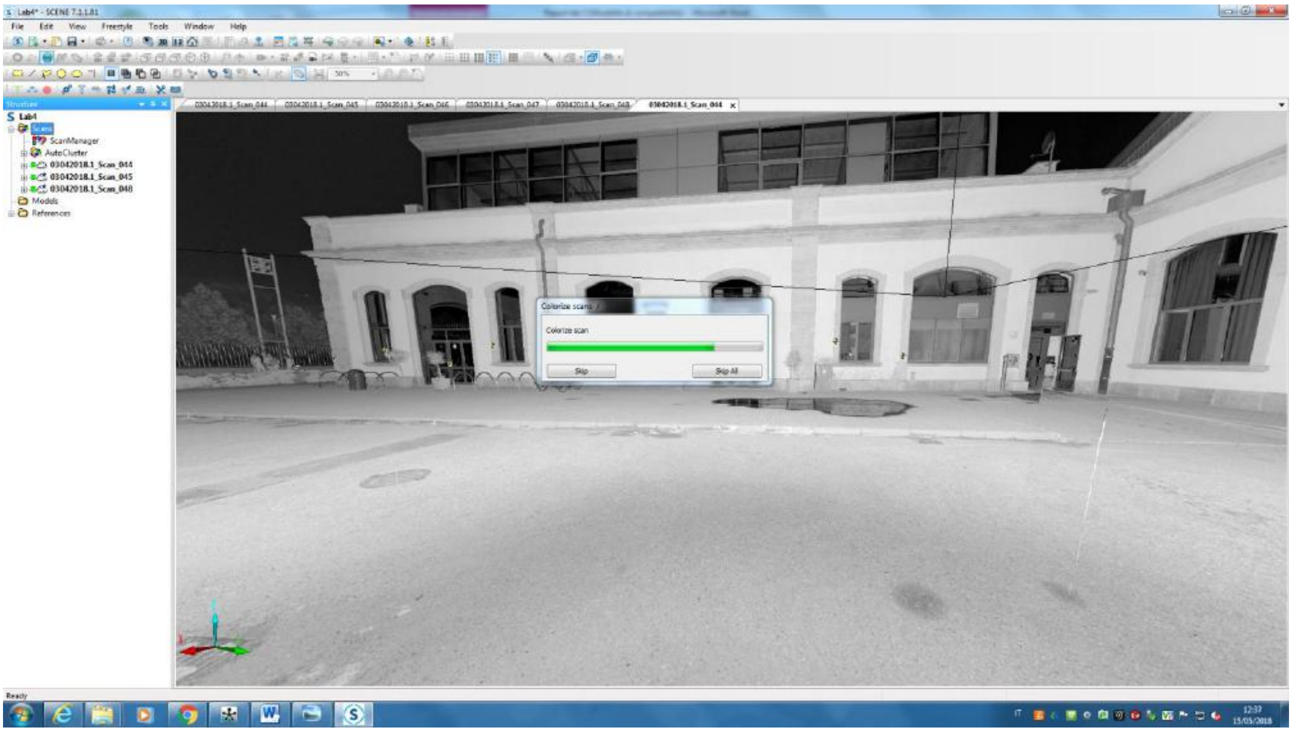
Click visualize, plan view:

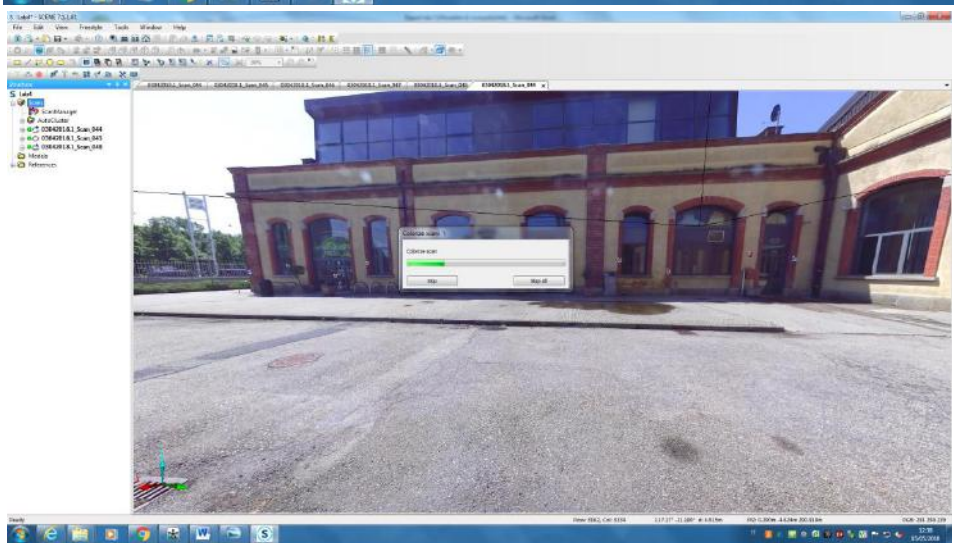


Remove the points that are not targets or by using the menu:





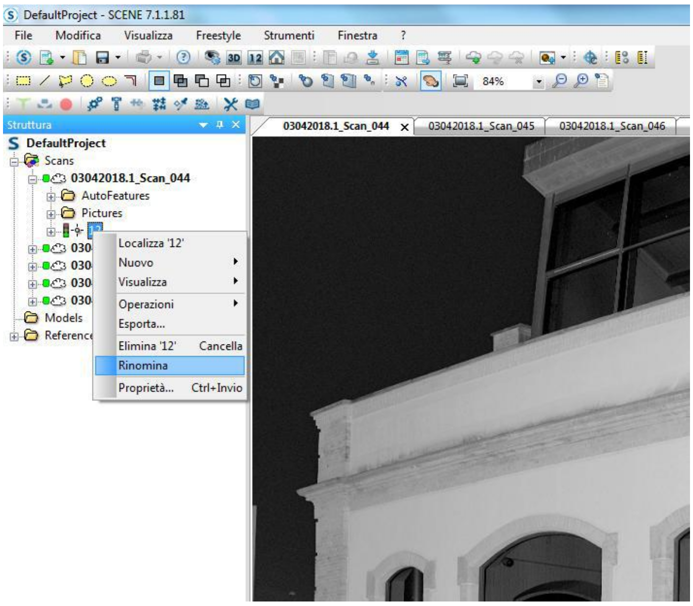


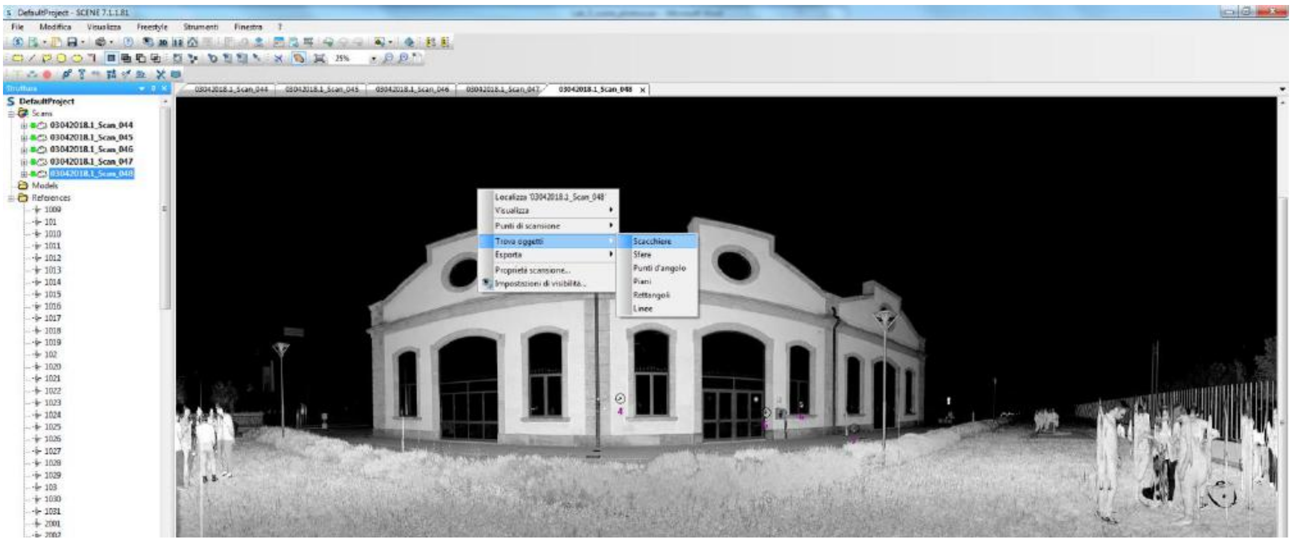


by Loredana Mihaela Chiforeanu

Lab 5 – SCENE

In the SCENE software we have to import all the scans, impose the planar view and find the checkboard points: we eliminate the wrong ones and add the unfounded ones, then we change their names as they were called in the field.





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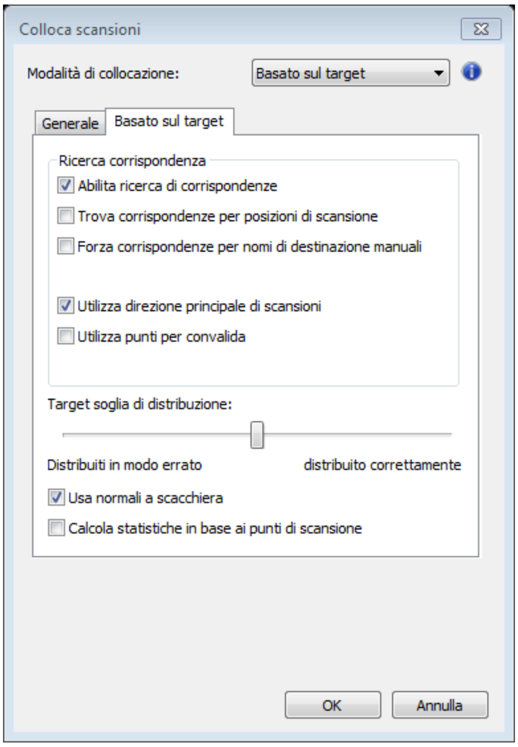
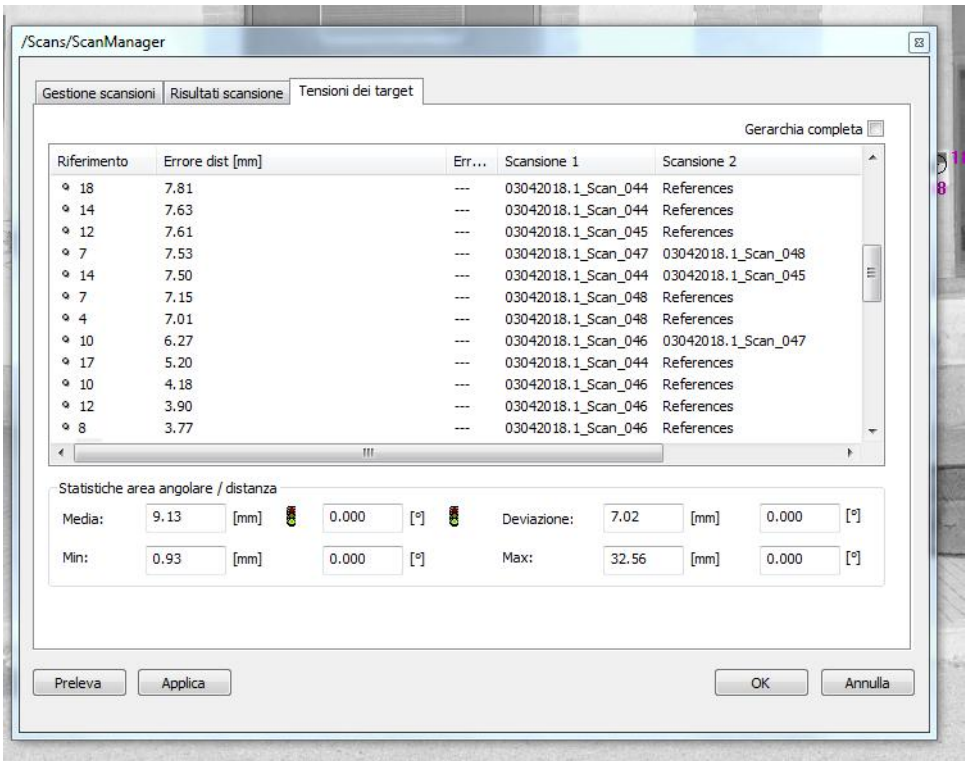


In “tensioni dei target” we can see the errors in the measurements of the distance: markers 6,7,8,9,10 are the ones with the best precision and accuracy.



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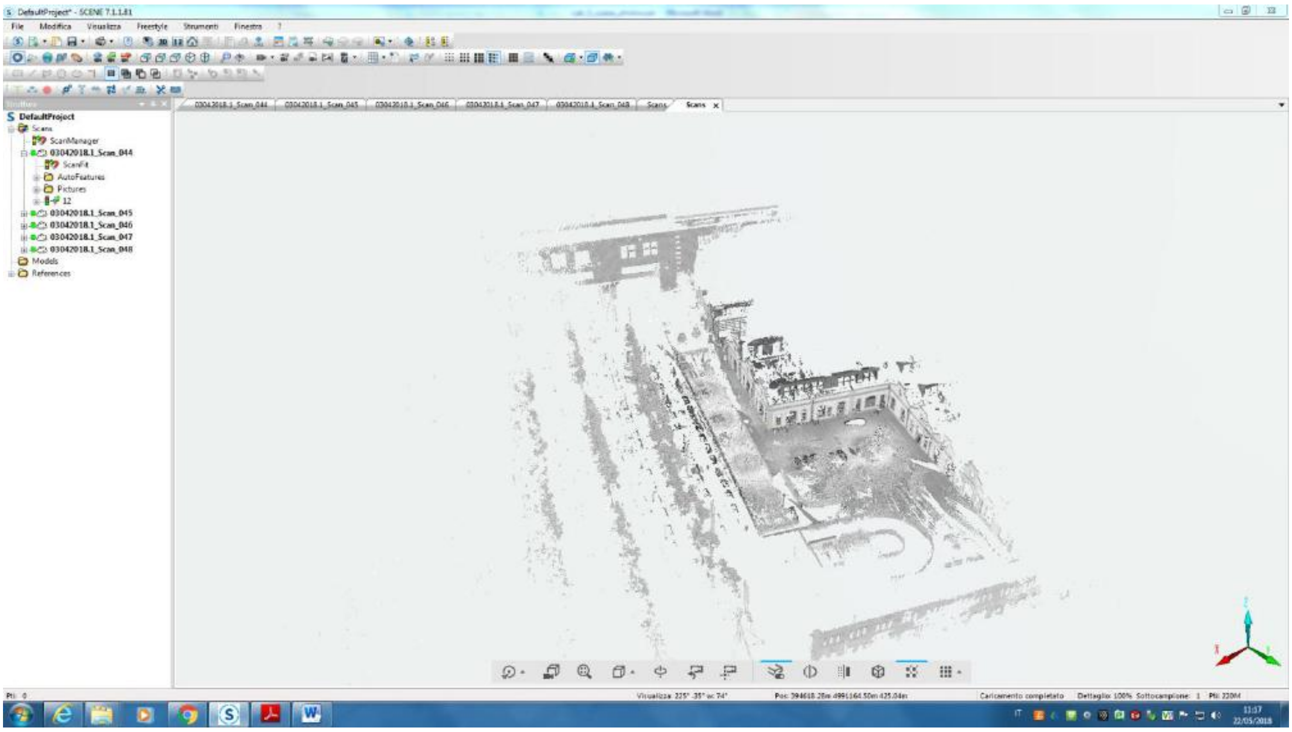
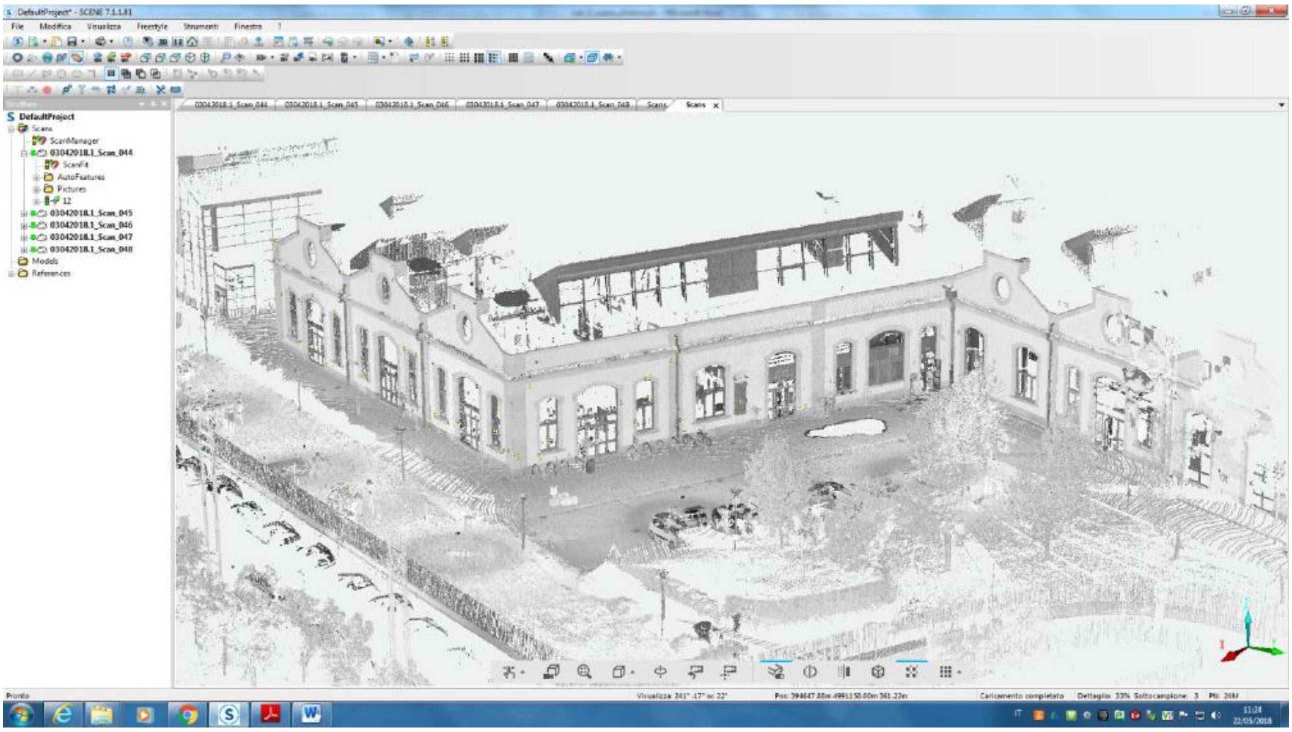


We can see that there are 220 million points (grey) but there are also a lot of white points where there is no information due to obstacles that have been intercepted by the laser signal.

There have been acquired also some points inside the building.

We can also apply colors to the points in order to see a more realistic model by this could be misleading because, if the laser scan and the photos hadn't been taken at the same time, there could be some not fitting parts due to objects (cars, doors, persons,…) that have moved.



Now we can export the model in different formats so we can use it in other softwares as Autocad:

Lab 7 – ArcGIS
PART 1

Ex 2.

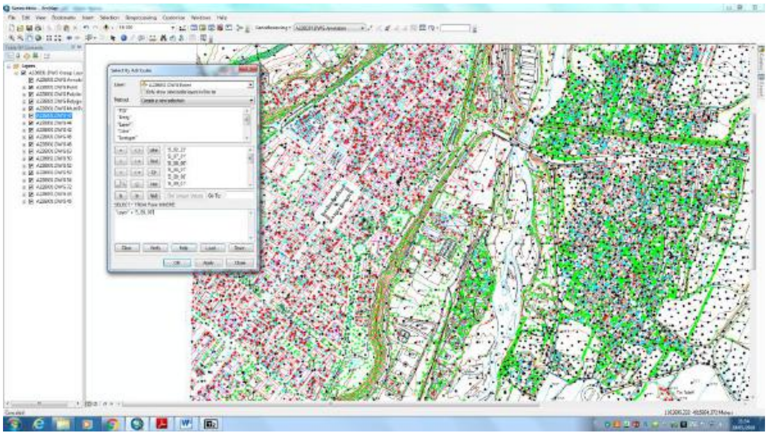
In order to create new smaller databases, i.e. extract only certain characteristics from the big database, we can make a selection by:

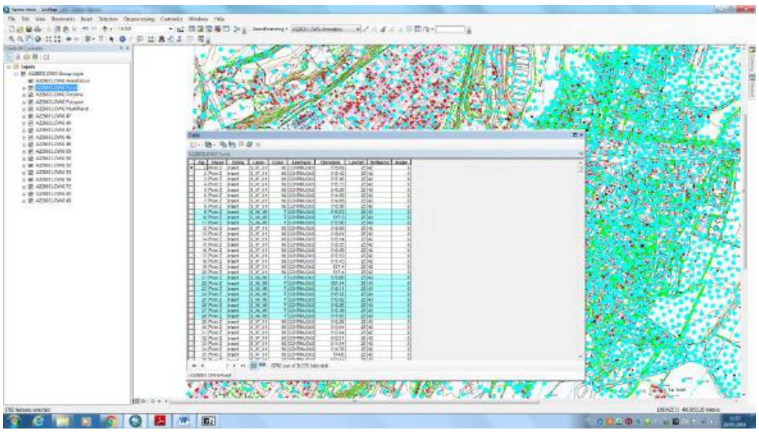
- Attributes: realize a query considering the attributes of the single feature
- Location: realize a query considering the position of the single feature

(Vector data: info is distributed in points, polygons and lines).

We have to input the .dwg files and choose *coordinates, project, national, Italy: Roma Monte Mario Italy 1.*

Now we can create the selection by attributes: the selected points are shown as cyan (color) points.

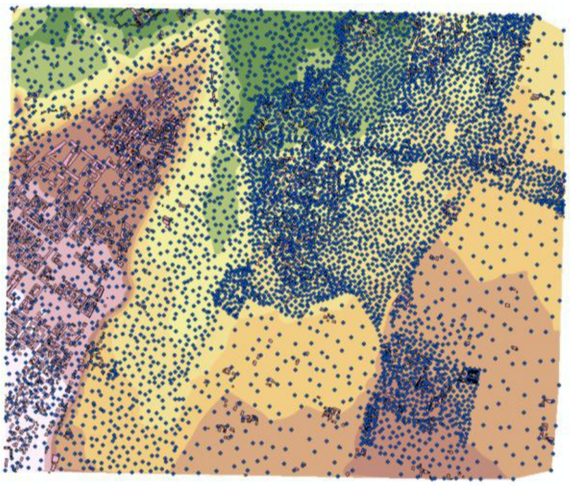


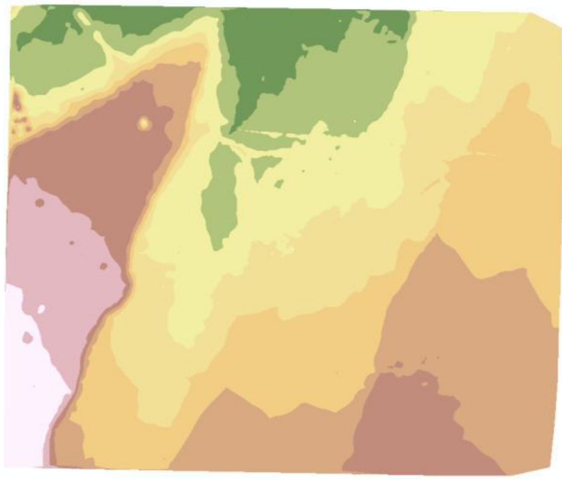


We have 5782selected points:

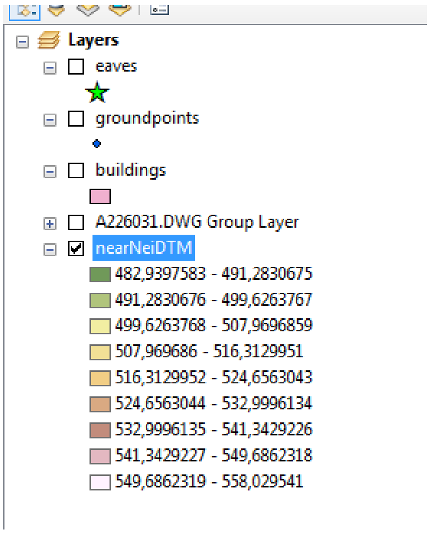
(5782 out of 31235 Selected)

We can export only these points as a shape file:

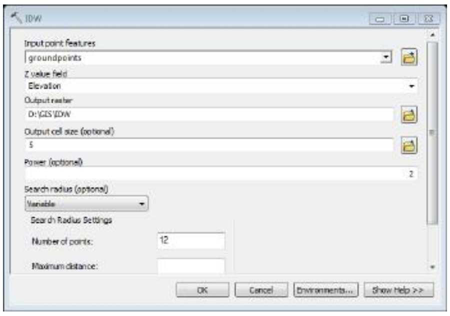


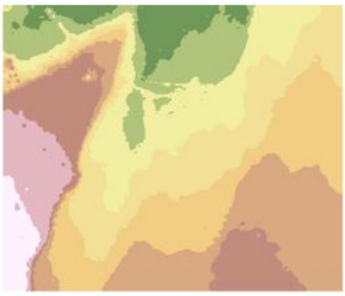


Elevations:



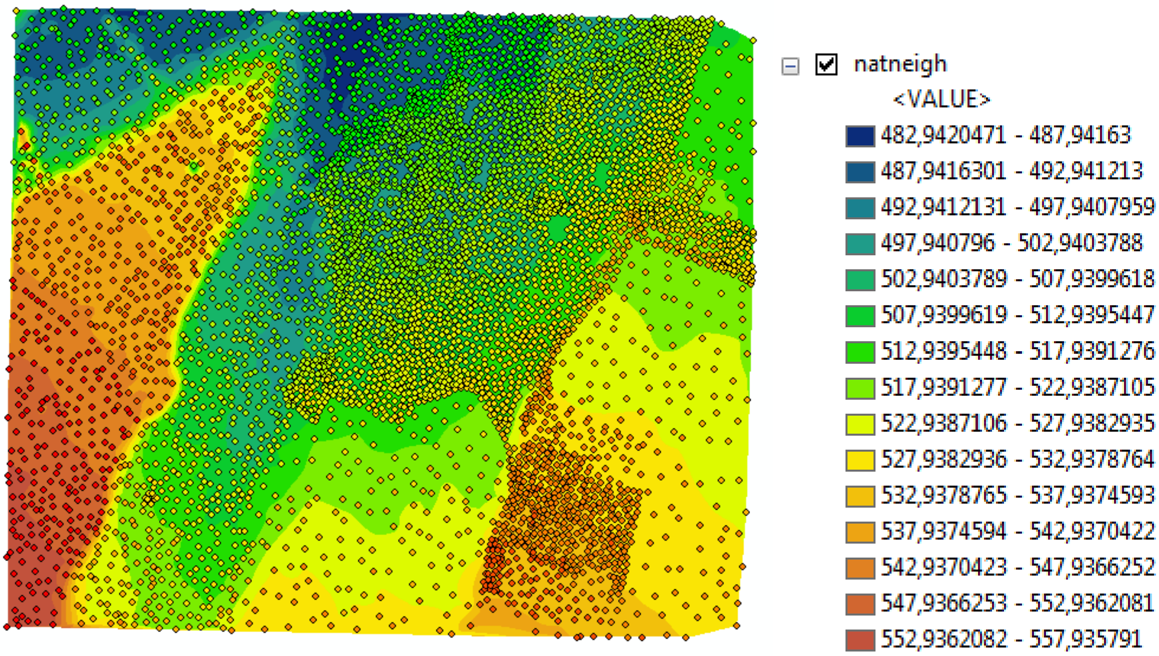
Or we can use the IDW model that creates a raster model, the results are:



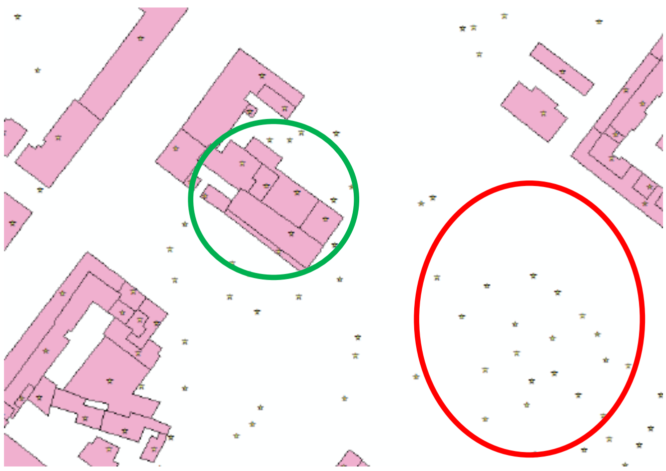


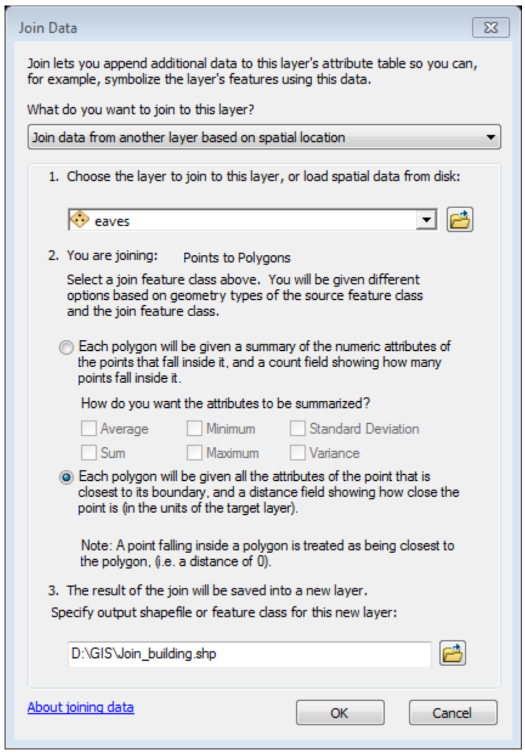
! Attribute tables are available only for vector data, because for raster the info is directly included in each cell.

Comparison between IDW and Nearest Neighbor: it's made by using the tools.

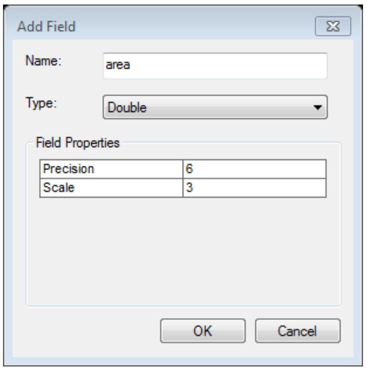


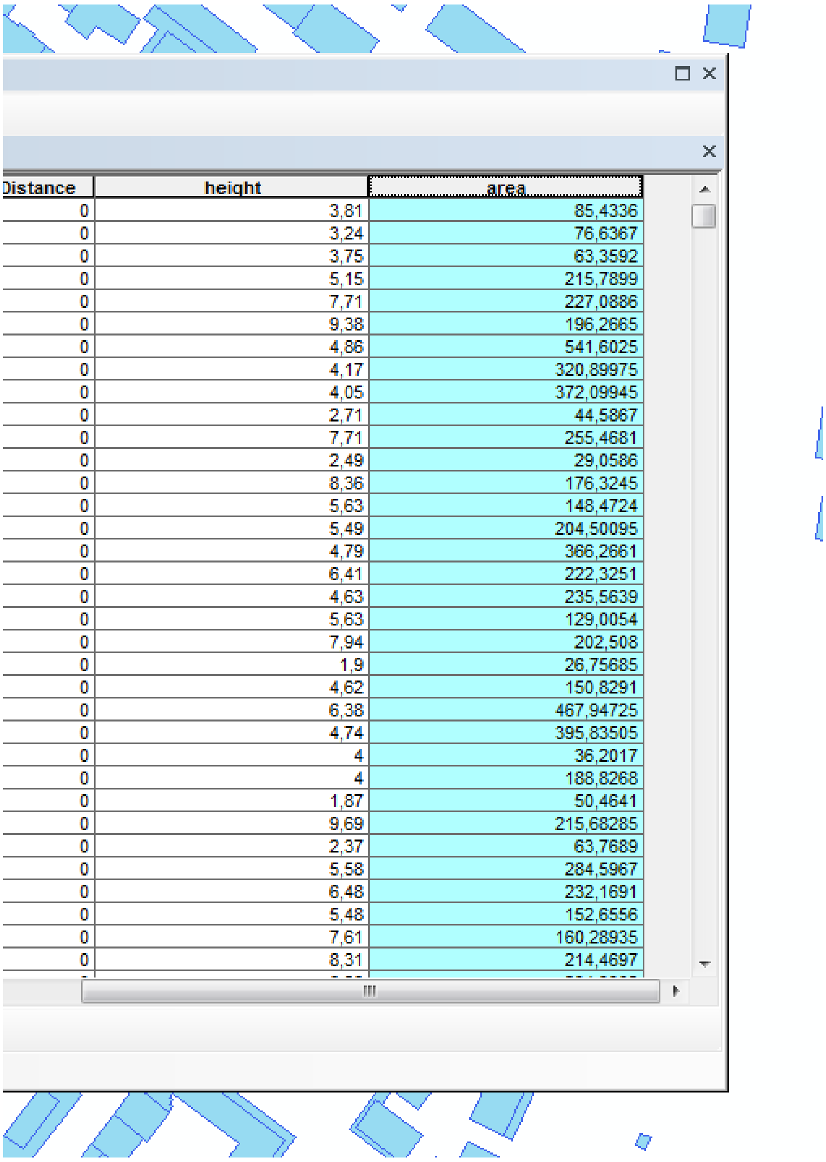
Now we want to merge info from the database with the building shapes and the database having the eave points. But we don't want the points that don't belong to buildings:





Calculate geometry is used to calculate areas, perimeters, coord of centroids: let's calculate the area (m^2):





Distance	height	area
0	3,81	85,4336
0	3,24	76,6367
0	3,75	63,3592
0	5,15	215,7899
0	7,71	227,0886
0	9,38	196,2665
0	4,86	541,6025
0	4,17	320,89975
0	4,05	372,09945
0	2,71	44,5867
0	7,71	255,4681
0	2,49	29,0586
0	8,36	176,3245
0	5,63	148,4724
0	5,49	204,50095
0	4,79	366,2661
0	6,41	222,3251
0	4,63	235,5639
0	5,63	129,0054
0	7,94	202,508
0	1,9	26,75685
0	4,62	150,8291
0	6,38	467,94725
0	4,74	395,83505
0	4	36,2017
0	4	188,8268
0	1,87	50,4641
0	9,69	215,68285
0	2,37	63,7689
0	5,58	284,5967
0	6,48	232,1691
0	5,48	152,6556
0	7,61	160,28935
0	8,31	214,4697

Represent the building with different colors consider the height

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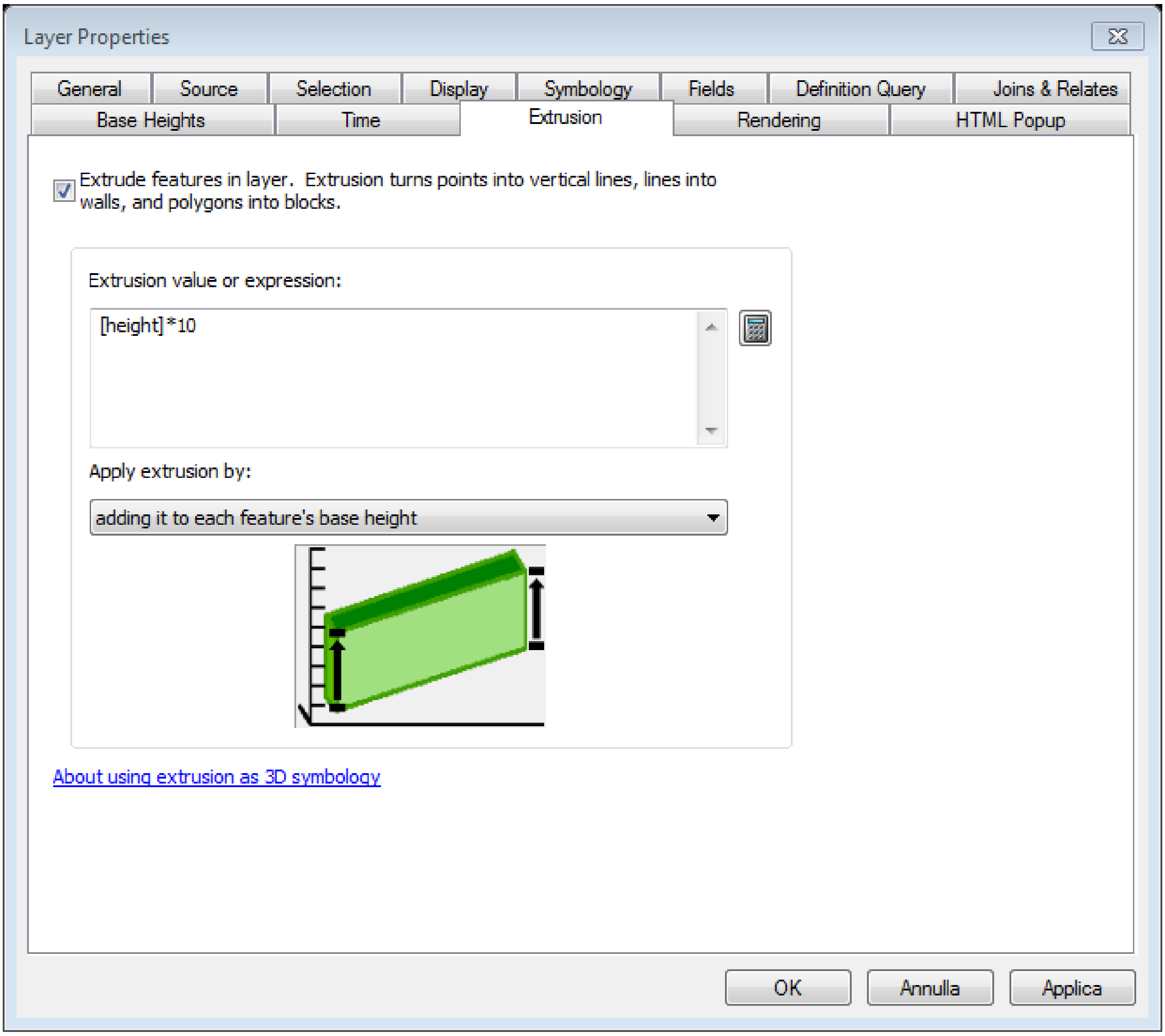
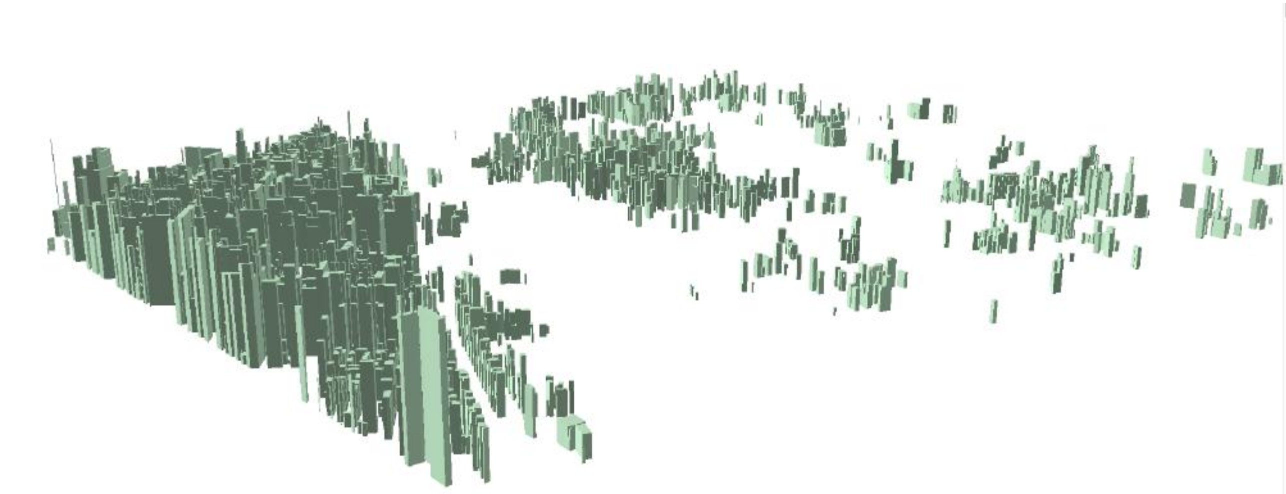


We amplified the view by multiplying by 10



But it’s too much so we reduce the amplification by 2:

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