Exercise 2

Objectives:
1. Investigation of point measurement accuracy using GIS-level GNSS receivers in three different conditions with and without averaging.
2. Getting experience in using statistical tools.

According to the given tasks the points in three different environments, such as open, urban, and vegetated area have been choose. Chosen point for open environment was located on sport field of UWH, for urban environment in Frankenburg Street, and for vegetated environment was located in territory of Botanic garden. Field observation works have been done with Leica 1200 series with geodetic accuracy and GIS-level GNSS receiver Trimble Juno. The field measurement works were started with GIS-level GNSS receiver Trimble-Juno and each marked points were measured twice per each day during five days. The cause of double measurement of each point was that the first time it was measured without averaging and the second time with averaging. For a second measurement time for observation was assigned for the 30 seconds and result of it was averaged. The difference between two measurements on each point was within 2-3minutes. The points, which were observed by help of specialised GPS receiver Leica 1200, were assigned as reference points. During the field measurement works with GPS receiver Leica 1200 the weather was clear and RTK observation method had been used.

For purposes of accuracy assessment and determining distribution of observed points around reference points **RStudio** software had been used. The office work was started with downloading all data from devices. Further all gathered data was entered to excel sheet in a form of table and saved as file with .csv extension. After, that file was imported to **RStudio** software environment. First step in **RStudio** was to plot the graphs about distribution of measured points with Trimble Juno around reference points (Figures 1:3). The second step was to plot a graph from, which it could be possible to determine dependency of PDOP from number of tracking satellites. And the third step was to numerically calculate and define errors of measured points in **Euclidean distance** from ground truth point in 2D and 3D spaces. For this purpose **Euclidean formula** d(p,q)=$\sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \dots\dots(q_n - p_n)^2}$ have been used.

Where: d-distance, q and p- Euclidean vectors, p is refers to the origin point in Euclidean space.

Table 1: .CSV extension file, which was imported to **RStudio** environment.

ID	Date	Environment	Mean	East	North	Elevation	PDOP	Nsatellites	ref_ east	ref_north	R_elev
1	4/5/2016	open	0	464629.4	262731.9	239.16	2.7	6	464627	262735.7	222.533
2	4/5/2016	open	1	464630.7	262727.9	245.56	2.02	7	464627	262735.7	222.533
3	4/5/2016	vegetation	1	464361.1	262591.5	245.71	2	9	464359.8	262590.6	233.403
4	4/5/2016	vegetation	0	464359.4	262591.9	246.36	2	9	464359.8	262590.6	233.403
5	4/5/2016	urban	1	464659.8	262906.3	244.44	2.92	6	464660	262910.4	219.403
6	4/5/2016	urban	0	464660.4	262911.1	238.66	2.2	8	464660	262910.4	219.403
7	4/6/2016	vegetation	1	464354.8	262591.6	249.23	2.5	6	464359.8	262590.6	233.403
8	4/6/2016	vegetation	0	464351.8	262591.2	253.36	2.1	7	464359.8	262590.6	233.403
9	4/6/2016	open	1	464626	262739	228.87	2.59	6	464627	262735.7	222.533
10	4/6/2016	open	0	464626.6	262737.1	228.06	2	8	464627	262735.7	222.533
11	4/6/2016	urban	1	464661.4	262905.2	228.83	2.51	6	464660	262910.4	219.403
12	4/6/2016	urban	0	464660.8	262906.8	229.36	2.3	7	464660	262910.4	219.403
13	4/7/2016	vegetation	1	464346.6	262604.3	251.72	3.5	5	464359.8	262590.6	233.403
14	4/7/2016	vegetation	0	464355.1	262593.3	266.36	3.5	5	464359.8	262590.6	233.403
15	4/7/2016	open	1	464628.9	262737.6	245.58	2.7	6	464627	262735.7	222.533
16	4/7/2016	open	0	464627.4	262737.1	245.46	2.7	6	464627	262735.7	222.533
17	4/7/2016	urban	1	464656	262908.5	238.81	2.7	5	464660	262910.4	219.403
18	4/7/2016	urban	0	464659.5	262911.3	239.96	2.6	6	464660	262910.4	219.403
19	4/8/2016	vegetation	1	464357.3	262590.5	232.73	2.4	7	464359.8	262590.6	233.403
20	4/8/2016	vegetation	0	464358.2	262589.9	228.86	2.3	8	464359.8	262590.6	233.403
21	4/8/2016	open	0	464627.5	262734	226.66	2.1	8	464627	262735.7	222.533
22	4/8/2016	open	1	464628.4	262733.2	234.15	2.1	8	464627	262735.7	222.533
23	4/8/2016	urban	0	464665.1	262906.3	230.86	1.9	7	464660	262910.4	219.403
24	4/8/2016	urban	1	464664.3	262906.6	230.45	1.94	7	464660	262910.4	219.403
25	4/9/2016	urban	1	464660.9	262909.4	242.38	2.89	6	464660	262910.4	219.403
26	4/9/2016	urban	0	464659.6	262908.3	244.36	2.9	7	464660	262910.4	219.403
27	4/9/2016	open	1	464631.6	262733.9	238.07	2.21	7	464627	262735.7	222.533
28	4/9/2016	open	0	464631	262731.6	246.26	2.2	8	464627	262735.7	222.533
29	4/9/2016	vegetation	1	464360.7	262583.7	264.34	2.02	8	464359.8	262590.6	233.403
30	4/9/2016	vegetation	0	464359.5	262581.9	269.66	2.1	8	464359.8	262590.6	233.403

Figure below shows points distribution around ground truth point, which was observed in open area.

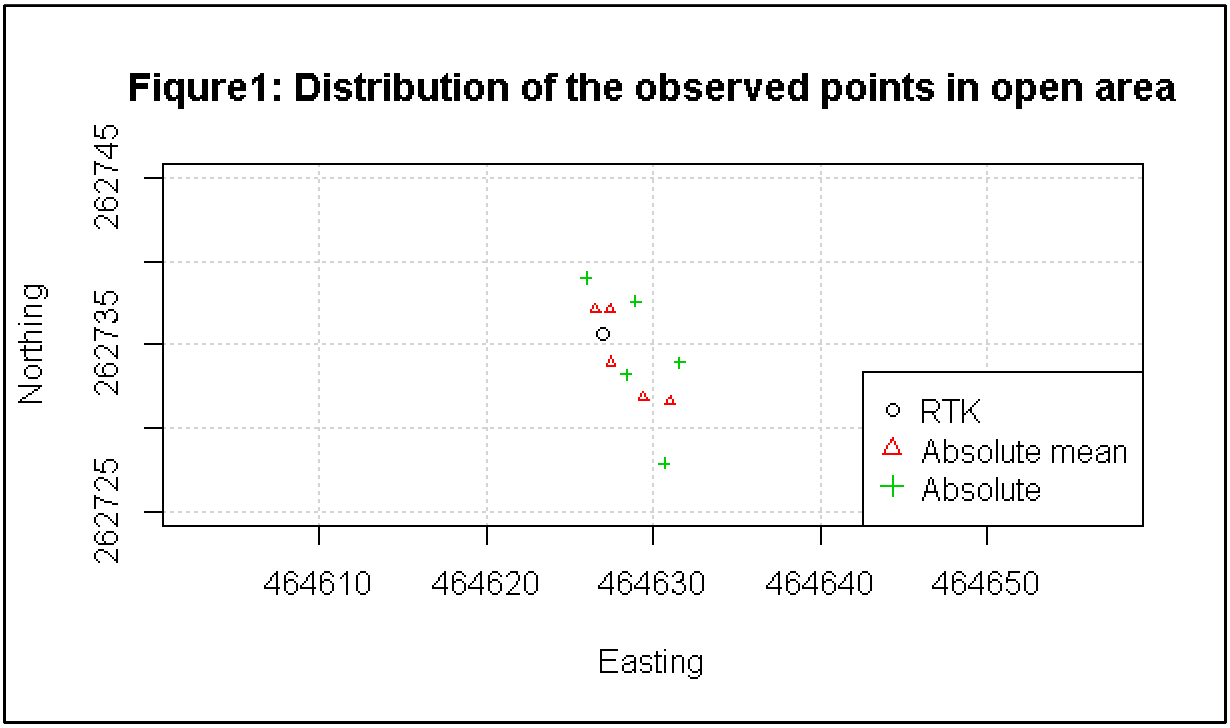


Figure below shows points distribution around ground truth point, which was observed in build-up area.

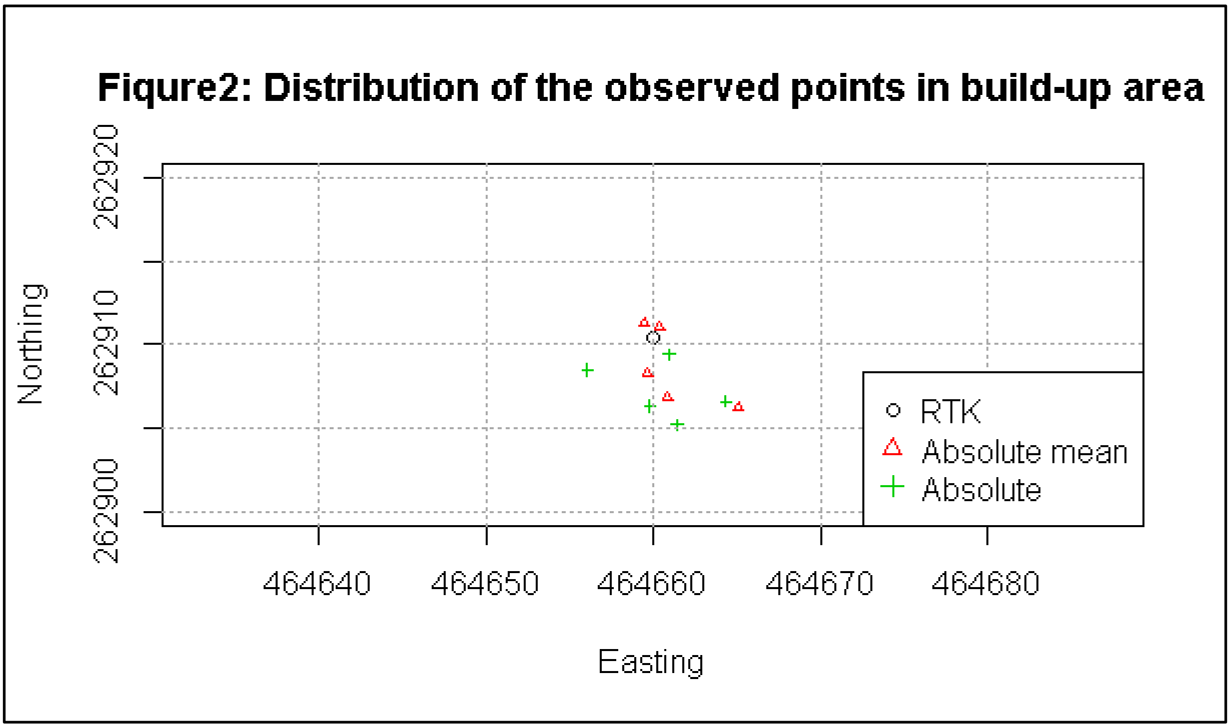


Figure below shows points distribution around ground truth point, which was observed in vegetated area.

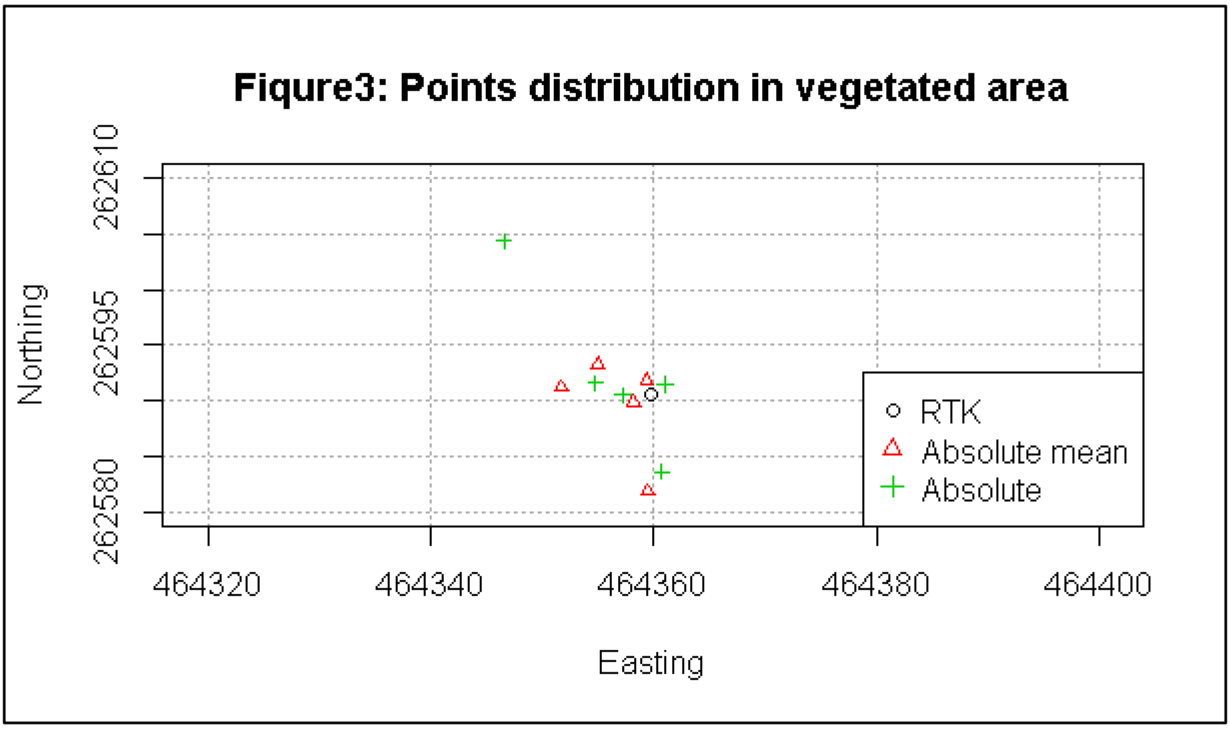
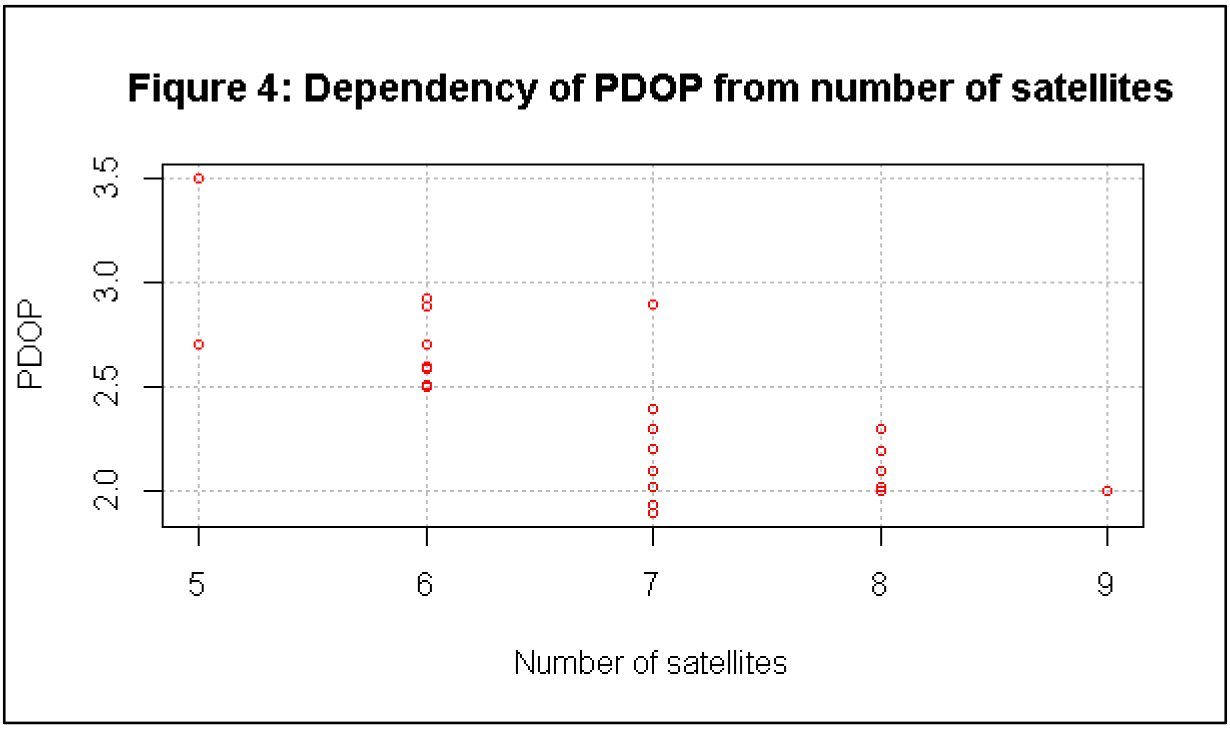


Figure below shows dependency of PDOP from number of tracking satellites.



Example of calculating Euclidean distance from the measured points to a reference point by help of “RStudio” software.

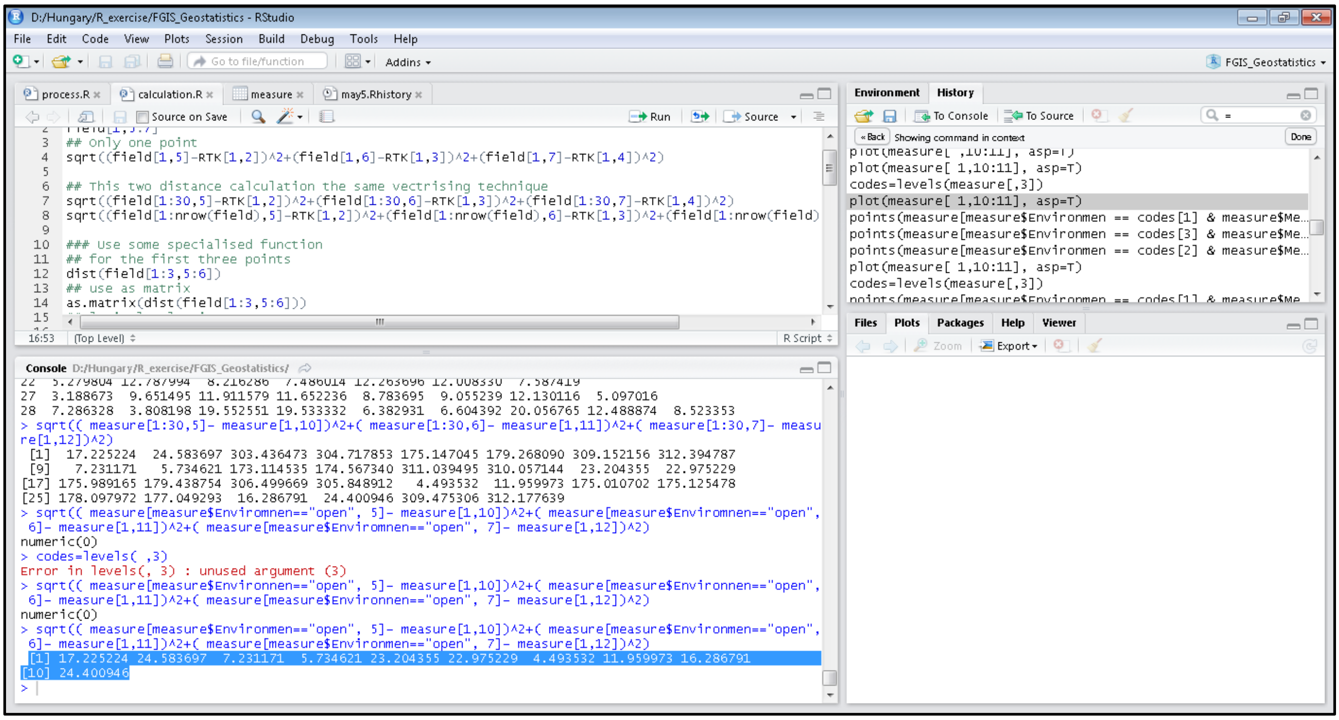


Table 2: Result of calculating Euclidean distance between a reference point and the measured points in 3D (X, Y, Z) space.

Differences of the observed points in different days from a reference point						
Environment	**Method**	**1 day**	**2 day**	**3 day**	**4 day**	**5 day**
Open area	**single**	**24.5837**	**7.231171**	**23.20436**	**11.95997**	**16.28679**
	averaged	**17.22522**	**5.734621**	**22.97523**	**4.493532**	**24.40095**
Build-up area	**single**	**25.36333**	**10.84325**	**19.88873**	**12.45529**	**23.0189**
	averaged	**19.27336**	**10.6185**	**20.58276**	**13.19683**	**25.04428**
Vegetated	**single**	**12.39756**	**16.6208**	**26.41351**	**2.632888**	**31.72941**
	averaged	**13.02263**	**21.52417**	**33.40135**	**4.866876**	**37.30284**

Table 3: Result of calculating Euclidean distance between a reference point and the measured points in 2D (X, Y) space.

Differences of the observed points in different days from a reference point						
Environment	**Method**	**1 day**	**2 day**	**3 day**	**4 day**	**5 day**
Open area	**single**	**8.609031**	**3.48314**	**2.697753**	**2.843637**	**4.884793**
	averaged	**4.500134**	**1.529099**	**1.487891**	**1.777554**	**5.695229**
Build-up area	**single**	**4.0555**	**5.357971**	**4.350876**	**5.753083**	**1.388247**
	averaged	**0.794028**	**3.689266**	**1.029412**	**6.549304**	**2.089069**
Vegetated	**single**	**1.495756**	**5.075124**	**19.03053**	**2.545421**	**7.046788**
	averaged	**1.305741**	**8.06275**	**5.430132**	**1.745747**	**8.77106**

Conclusion: From the figures, which are shown above it's not clear, that averaging is improving the accuracy of measurement or not, because by visual interpretation it's difficult to distinguish it. However it was clear by interpreting Figure 4, that quality of PDOP directly **depend** from number of tracking satellites by receiver. Concerning question does averaging improving accuracy or not?.

By interpreting Table 2 it is difficult to say that averaging improves accuracy, yes somewhere it is improving, but somewhere it shows worse result than single measurement in 3D space. It has to be note that environmental condition should be considered when the users going to choose either averaging or non-averaging methods.

By interpreting Table 3, which showing Euclidean distance between ground truth point and measured points in 2D space it's clear, that averaging is enhancing accuracy. So it can be say the averaging method maybe is not sophisticated for determining position in 3D space, but obviously it is clear, that this method is more accurate and reliable for horizontal positioning than single measurement.