Remove-Restore Technique
for Improving the Datum Transformation Process

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ABSTRACT

The geodetic datum transformation is still an important issue specially these days where GPS is used extensively. In Egypt and many other countries, obtaining an accurate-consistent transformation parameters set is not an easy task. This is because of the inaccuracy and inconsistency in the local geodetic networks. In Egypt, the first order triangulation network is adjusted many times in the university researches. More accurate coordinates than those of the Egyptian Surveying Authority (ESA) are obtained. The adjusted coordinates are also used in computing better transformation parameters. The adjusted coordinates are not adopted in ESA because the whole surveying works in Egypt for about 70 years are based on ESA coordinates. Therefore any better transformation set are not used because it produces transformed coordinates do not match the corresponding coordinates in ESA. In this research, local adjusted coordinates are used in the transformation process to be done in more accurate atmosphere. Then the resulted transformed coordinates are modified to match their corresponding values in ESA. The followed procedures are done in such (remove – transform – restore) process. This process improved the transformation results significantly while the resulted coordinates are still belonging to those of ESA. It is known that the Egyptian triangulation network consists of two main parts and the precision of their coordinates are different and not constant allover the network. The available GPS coordinates are also different in their precision according to the way of collecting and processing the data. So, the effect of using weights in the transformation process is also investigated in this research.

1. INTRODUCTION

Nowadays, GPS is used in most of the geodetic and surveying applications. GPS is faster than the traditional surveying instruments beside that it works kinematiclly. The resulted coordinates of GPS, in its relative (surveying) mode are very accurate but they are defined in WGS-84. In most of the cases, WGS-84 coordinates have to be transformed into the Local Datum (LD). So, the transformation process is still strongly needed. The transformation process depends on a mathematical model and a number of common points. For good transformation process, the adopted mathematical model should be adequate and rigorous. The common points also should be enough, accurate in both systems, and well distributed.
In Egypt, the mapping system, surveying and civilian applications depends mainly on the first order geodetic triangulation network which is computed and defined on the local Egyptian

Datum. This network consists of two parts, Network I and Network II. Network I has good observations and some defects in the processing and the adjustment. So, its precision is not the same everywhere and could be more or less 1:100,000, [Saad and Elsayed, 2005]. The observations of Network II are less in quality than those of Network I and it is not subjected to an adjustment process. So, the precision of Network II is less than that of Network I and could be more or less 1:50,000 [Ibid]. The inconsistency in the precision along the whole network is the permanent reason that it is not easy to obtain a consistent (precise) transformation set for the whole area of Egypt.

Previous work is done by many researchers to solve the transformation problem in Egypt. Some of these trials are as follows:

- [Saad et al, 1998] computed 8 sets of transformation parameters in Egypt. One set was for the whole area of Egypt and two sets were for Egypt as two halves. Other five sets were for Egypt as five zones.
- [Elmewafi et al, 2003] used the Minimum Curvature Surface (MCS) as a transformation tool. The obtained results are compared with the corresponding results of the classical seven parameters models.
- [Saad et al, 2005] investigated the behavior of the polynomials in the transformation process. The number of the data points and the spacing between them are studied for optimum implementation of the adopted polynomials. The results are assessed at data and check points.

- [Abd-Elmotaal, 1994] presented the comparison of polynomial and similarity transformation based datum shifts for Egypt. He used 8 common points from first order geodetic stations known in both WGS84 and Egyptian Datum as data points and no check points are used. The results for both similarity transformation by using Bursa model and the coefficients of the surface polynomial second order showed that the polynomial is better than Bursa model.
- [El-Tokhey, 1999] computed transformation parameters between the Egyptian Datum and WGS-84 by using two models (Bursa model and two dimensional surface polynomials second order). He used 15 common points from the Egyptian Survey Authority (ESA) project of the High Accuracy Referance Network (HARN) as data points. [EL-Tokhey, 1999] concluded that the used polynomials are better than Bursa model.
- [Gomaa and Alnaggar, 2000] presented the geodetic datum transformation techniques for GPS surveys in Egypt by using two groups (similarity models Bursa and Molodensky) and (two dimensional surface polynomials multiple regression). The available geodetic coordinates were19 first order geodetic stations known in both WGS84 and ED and 15 common points were used as solution points. Four stations have been considered as check points. The results showed that multiple regression is better than Bursa and Molodensky according to [Gomma and Alnaggar, 2000].

- [Shaker et al, 2003] compared several mathematical models of coordinate transformations. They investigated 12 models including different kinds of polynomials. The main conclusion was that the polynomials have better results at the data points but not necessarily at the check points. Optimum data points and optimum spacing among the data points are investigated for the optimum implementation of the used polynomial in transformation process.

The work of this research will go in two directions. The first direction will focus on investigating the effect of using weighted coordinates in the transformation process. So, 5 solutions using equal weight versus weighted coordinates are made. The solutions are assessed at the solution points as well as the check points.
The second direction will focus on investigating the effect of using modified (improved) local coordinates instead of using the local (ESA) coordinates in the transformation process. The local (ESA) coordinates are modified (improved) in the way explained in [Saad and Elsayed, 2005], the modification process is considered here as removing process. The modified coordinates are used with their corresponding WGS-84 coordinates in the transformation process. The modified coordinates are more consistent and less biased than their corresponding ESA coordinates, so it is expected that the transformation process will be more accurate than that one used ESA coordinates. The results of this transformation (transformed coordinates) will not match ESA coordinates, so the removed part will be restored to the transformed coordinates to make them match ESA coordinates. Therefore it is (remove – transformation – restore) process to guarantee that the transformation process will happen in less erroneous field, and the coordinates will be back in ESA system of coordinates. Two solutions are made to investigate this process. The solutions are assessed at the solution and the check points.

2. THE AVAILABLE USED DATA

The data used in this research are the geodetic coordinates of first order triangulation stations. The computations of this research are done in two groups. Group1 solutions are made to compare between using equal weight coordinates and using weighted coordinates in the transformation process. The available data which are used in group 1 solutions are 34 common points, Figure (1). The common point is a known point in the two concerning geodetic datums or coordinate systems, in this work the two geodetic datums are the Egyptian Datum (ED) and WGS-84. Group 2 solutions are made to compare between using equal weight coordinates, equal weight-modified coordinates, and weighted coordinates in the transformation process. The available data which are used in group 2 solutions are 24 common points, Figure (2). The used data points in this research can be described as follows:

- The geodetic coordinates of 34 first order triangulation stations known in the Egyptian Datum, 26 of them belong to Network I and 8 of them belong to Network II. The precision of Network I stations is taken 1:100,000 and that of Network II stations is taken 1:50,000 based on an error analysis made in [Saad and Elsayed, 2005].

- The geodetic coordinates of the above mentioned 34 stations defined in WGS-84. 15 stations of them belong to the High Accurate Reference Network (HARN) with precision 1:10,000,000 [ESA, 1995]. Other 7 stations belong to the Egyptian Aviation project with precision 1:7000,000, [Aviation report, 1997]. The other 12 stations belong to the National Agricultural Cadastral Network (NACN) with precision 1:1000,000, [Powell, 1997].
- The modified (improved) coordinates of 24 stations included in the above mentioned 34 stations known in the Egyptian datum. The local datum coordinates of those 24 stations have been modified (improved) using accurate GPS coordinates and following simple polynomial model in [Saad et al, 2005].

3. METHODOLOGY

The computations of this research are made in two groups of solutions. Group 1 is specified for the comparison between using equal weight and using weighted coordinates in the transformation process. Group 2 is specified for the investigation of using equal weighted coordinates, using improved coordinates, and using weighted coordinates in the transformation process.
To achieve the first target of the research, the local and WGS-84 coordinates of the above mentioned 34 stations are used in the solutions as follows:

- **Solution 1:** Seven transformation parameters are computed with their standard deviations using all the 34 stations. The computations are done once with equal weight coordinates and once more using weighted coordinates. In both cases, the residuals at the 34 solution stations are computed.
- **Solution 2:** Seven transformation parameters are computed with their standard deviations using 30 stations. The highest four residuals stations are excluded from the solution and used as check points. The computations are done once with equal weight coordinates and once more using weighted coordinates. In both cases, the residuals at the 30 solution stations and at the 4 check stations are computed. This solution is made to clarify the effect of excluding the stations of high residuals on the solution.
- **Solution 3:** Seven transformation parameters are computed with their standard deviations using 25 stations. The computations are done once with equal weight coordinates and once more using weighted coordinates. In both cases, the residuals at the 25 solution stations and 5 check stations are computed.
- **Solution 4:** Seven transformation parameters are computed with their standard deviations using 15 stations. The computations are done once with equal weight coordinates and once more using weighted coordinates. In both cases, the residuals at the 15 solution stations and the 5 check stations are computed.
- **Solution 5:** Seven transformation parameters are computed with their standard deviations using 10 stations. The computations are done once with equal weight coordinates and once more using weighted coordinates. In both cases, the residuals at the 10 solution stations and the 5 check stations are computed.

To achieve the second target of the research, the local, modified local, and WGS-84 coordinates of the above mentioned 24 stations are used in the solutions. In the beginning the local datum coordinates are modified (improved) using the way explained in [Saad and Elsayed, 2005]. Now the improved coordinates are not ESA coordinates any more. The improved coordinates are used with their corresponding WGS-84 coordinates to compute the transformation parameters. The parameters are used to transform the coordinates of the points. The transformed coordinates are anti-modified again to be back in ESA system of coordinates. The solutions are made as follows:

- **Solution 6:** Seven transformation parameters are computed with their standard deviations using all the 24 stations. The computations are done firstly with equal weight coordinates, secondly with the modified coordinates, and thirdly using weighted coordinates. In three cases, the residuals at the 24 solution stations are computed.
- **Solution 7:** Seven transformation parameters are computed with their standard deviations using 19 stations and the other 5 stations are excluded for checking the solution. The computations are done firstly with equal weight coordinates, secondly with the modified coordinates, and thirdly using weighted coordinates. In three cases, the residuals at the 19 solution stations as well as the 5 check stations are computed.

The 7 parameters Bursa model for transformation is used in all cases. The model is programmed for the computations in both cases of using equal weights and weighted coordinates. Bursa model can be found in many references, the reader can refer to e.g. [Nassar, 1994].

4. COMPUTATIONS AND RESULTS

The above mentioned solutions are made. The seven transformation parameters are computed in every case. The latitude and longitude residuals are computed at the solution points and also at the check points when they are available. The mean of the absolute residuals and the standard deviation are computed for the different solutions. The results of the solutions are tabulated in two groups as follows:

4.1 Group 1 Solutions

Recalling that, the solutions of group 1 are made to compare between using equal weight coordinates and using weighted coordinates in the transformation process. Five solutions of group 1 are computed and their results are obtained.

4.1.1 The Seven Parameters from Group 1 Solutions

The obtained seven parameters in every case are collected in one table for the easiness of comparison.

Table (1): Seven parameters with their standard deviations from group 1 solutions

	Solution 1 (34Pts)		Solution 2 (30 Pts)		Solution 3 (25 Pts)		Solution 4 (15 Pts)		Solution 5 (10 Pts)	
	Eq. W	weighted	Eq. W	weighted	Eq. W	weighted	Eq. W	weighted	Eq. W	weighted
DX (m)	22.85 ±44.10	-3.98 ±0.02	-15.40 ±60.44	-29.76 ±0.02	-36.90 ±71.52	-51.29 ±0.02	-162.47 ±134.06	-161.91 ±0.02	-203.72 ±335.44	-201.51 ±0.04
DY (m)	82.03 ±51.57	105.42 ±0.02	107.52 ±73.50	126.61 ±0.02	118.93 ±89.12	138.42 ±0.02	218.55 ±169.13	218.13 ±0.03	266.83 ±615.75	263.87 ±0.05
DZ (m)	88.50 ±27.51	100.65 ±0.01	104.71 ±31.83	111.83 ±0.01	126.60 ±36.75	133.82 ±0.01	240.69 ±65.04	240.36 ±0.01	265.24 ±74.93	264.77 ±0.02
RX sec	-.904 ±4.87	-0.992 ±1.70	-0.857 ±5.701	-1.035 ±1.79	-0.677 ±7.04	-0.857 ±2.0	-0.612 ±1.20	-0.614 ±2.47	-0.601 ±3.42	-0.565 ±1.32
RY sec	-2.918 ±9.72	-3.563 ±2.49	-3.759 ±1.23	-4.149 ±2.64	-4.604 ±1.42	-4.995 ±2.83	-9.372 ±2.66	-9.358 ±1.16	-10.360 ±4.09	-10.316 ±1.44
RZ sec	6.847 ±1.57	7.893 ±1.06	8.205 ±2.283	8.890 ±1.19	8.822 ±2.74	9.520 ±1.31	13.056 ±5.22	13.036 ±1.62	15.089 ±1.78	14.983 ±3.01
S	-7.498 ±4.08	-6.872 ±1.52	-6.073 ±4.60	-6.201 ±1.57	-6.042 ±5.58	-6.203 ±1.74	-6.734 ±9.31	-6.749 ±2.17	-7.530 ±1.44	-7.547 ±2.7

In the first three solutions, the three shift parameters are significantly different in both cases. The other four parameters are not much different in both cases. The standard deviations of the parameters are too small in the case of using weighted coordinates compared with their corresponding values in the case of using equal weight coordinates specially the three shift parameters. The parameters in the last two solutions are close to each others in both cases, while the standard deviations of the parameters in the case of using weights are too small compared with their corresponding values in the case of using equal weights. The parameters of the equal weight and also weighted solutions are affected by excluding points from the solutions.

Using the resulted seven parameters in every case, transformed local datum coordinates are obtained. The residuals of the solution at solution points and check points are obtained by subtracting the transformed coordinates from their corresponding original coordinates.

4.1.2 Latitude Residuals of Group 1 solutions

Latitude residuals from the five solutions are collected in Table (2).

Table (2): Latitude residuals at solution points from group1 solutions, units in meters

Pt.	Solution 1 (34 Pts)		Solution 2 (30 Pts)		Solution 3 (25 Pts)		Solution 4 (15 Pts)		Solution 5 (10 Pts)	
	Eq. w	w	Eq w	w	Eq w	w	Eq w	W	Eq w	w
A4	-0.92	-0.14	-0.81	-0.15	-0.72	-0.14	-0.92	-0.16	-0.96	-0.17
A5	-1.21	-0.02	-0.81	-0.02	-0.68	-0.02	-0.92	-0.01	-0.98	-0.02
D8	-0.15	-0.01	-1.43	-0.03	-1.48	-0.20	-1.18	-0.02	-1.90	-0.03
O5	-0.15	0.00	0.41	0.01	0.60	0.00	0.82	0.01	0.56	0.01
Q5	-0.15	0.00	0.38	0.01	0.56	0.02	0.86	0.02	0.56	0.01
A3	-0.15	0.04	1.33	0.04	1.30	0.04	1.40	0.04	1.16	0.03

E7	0.49	0.00	-0.35	-0.01	-0.36	0.00	-0.04	0.00	-0.34	0.00
F6	0.93	0.01	0.18	0.01	0.16	0.00	0.52	0.01	0.48	0.01
O1	0.90	0.01	0.17	0.01	0.16	0.00	0.48	0.01	0.38	0.01
A6	0.88	0.01	0.29	0.01	0.30	0.00	0.66	0.01	0.90	0.02
Z9	-1.20	-0.04	-3.21	-0.06	0.90	0.02	0.82	0.01		
M3	0.88	0.01	0.88	0.02	-1.42	-0.06	-3.7	-0.07		
A2	1.30	0.18	0.67	0.13	0.64	0.14	0.86	0.16		
L2	1.63	0.25	1.09	0.20	1.06	0.20	1.22	0.22		
P4	-1.34	-0.02	-0.95	-0.02	-0.82	-0.02	-1.10	-0.02		
E5	-1.24	-0.02	-0.74	-0.02	-0.60	-0.02				
L5	-0.36	0.00	0.21	0.00	0.38	0.00				
Y5	-0.32	-8.24	0.34	0.01	0.54	0.00				
N7	-0.19	-0.10	-1.21	-0.20	-1.22	-0.20				
B11	2.42	0.02	2.24	0.02	2.22	0.02				
F1	0.85	0.09	0.08	0.03	0.07	0.04				
B20	0.55	0.00	0.75	0.01	0.76	0.00				
A19	-2.49	-0.20	-1.91	-0.19	-1.80	-0.18				
T2	1.81	0.03	1.43	0.03	1.40	0.02				
A11	-0.03	0.00	-0.21	-0.01	-0.16	-0.02				
S2	1.83	0.30	1.40	0.26						
R5	-0.31	8.96	0.37	0.01						
B4	-0.12	0.00	-0.01	0.00						
X8	-0.69	-0.02	-2.37	-0.05						
B3	1.84	0.30	1.50	0.27						
C17	-8.81	-0.84								
A16	8.42	0.78								
B19	-6.21	-0.06								
I15	-0.20	-0.02								
mean	1.50	0.60	0.92	0.06	0.81	0.05	1.03	0.05	0.82	0.03
St Dv	2.13	2.04	0.77	0.08	0.55	0.07	0.81	0.07	0.47	0.05

The latitude residuals at the solution points in the weighted solutions are very small at the absolute scale and also compared with their corresponding values in the equal weight solutions except at the two points Y5 and R5. Points C17, A16, and B19 have big latitude residuals in the 34 points equal weight solution. Those points belong to local Network II which has not good accuracy.

Solution 1 used all the available points. Solution 2 excluded 4 points having the highest residuals in solution 1. Solution 3 excluded 5 more points and used them as check points. Solution 4 used only 15 points and solution 5 used only 10 points. Then, the number of the used solution points is not the same in the different 5 solutions, so the mean and the standard deviations are computed.

Excluding the four points of the highest residuals improved the solutions in both cases of using weights and using equal weights. Excluding points from the solutions improves the residual mean value in the case of using weights and this is not always true in the case of using equal weights. The latitude residuals are very small in the case of using weights.

For checking the solutions, the residuals at 5 check points are computed. Solutions 3, 4, and 5 used the same check points and the residuals at those points were as follows:

Table (3): Latitude residuals at check points from group 1 solutions, units in meters

Pt.	Solution 3 (25 Pts)		Solution 4 (15 Pts)		Solution 5 (10 Pts)	
	Eq w	w	Eq w	w	Eq w	w
S2	1.38	1.39	1.52	1.53	1.13	1.12
R5	0.57	0.55	0.85	0.84	0.58	0.57
B4	0.03	-.059	-0.13	-0.13	-0.15	-0.16
X8	-2.52	-2.50	-2.43	-2.41	-3.73	-3.71
B3	1.47	1.48	1.57	1.58	1.33	1.32
mean	1.19	1.20	1.30	1.30	1.39	1.38
St Dv	0.95	0.94	0.86	0.86	1.39	1.38

The latitude residuals at the check points from both solutions of using equal weights and using weighted coordinates are almost identical. So using weights does not improve the solution at the check points.

4.1.3 Longitude Residuals of Group 1 Solutions

Longitude residuals from the five solutions are collected in Table (4).

Table (4): Longitude residuals at the solution points from group 1 solutions, units in meters.

Pt.	Solution 1 (34 Pts)		Solution 2 (30 Pts)		Solution 3 (25 Pts)		Solution 4 (15 Pts)		Solution 5 (10 Pts)	
	Eq. w	w	Eq w	w	Eq w	w	Eq w	w	Eq w	w
A4	-0.87	-0.05	0.39	0.10	0.50	0.12	0.46	0.08	1.28	0.22
A5	-1.13	-0.01	0.28	0.01	0.36	0.00	-0.14	0.00	1.00	0.02
D8	-2.29	-0.04	-1.28	-0.03	1.44	-0.02	-1.42	-0.02	-2.34	-0.04
O5	-2.29	-0.06	-1.92	-0.04	-1.92	-0.04	-2.90	-0.06	-1.46	-0.02
Q5	-2.29	-0.09	-2.10	-0.06	-2.10	-0.06	-3.12	-0.08	-1.66	-0.04
A3	-2.29	0.04	2.10	0.07	2.38	0.06	2.58	0.07	2.94	0.08
E7	-0.87	-0.01	0.08	0.00	0.12	0.00	0.42	0.00	-0.07	0.00
F6	-1.12	-0.02	-0.33	-0.01	-0.34	0.00	0.06	0.00	-0.46	-0.01
O1	-1.10	-0.02	-0.25	-0.01	-0.24	0.00	0.14	0.00	-0.32	0.00
A6	0.23	0.01	0.86	0.02	1.00	0.02	1.60	0.02	1.14	0.02

Z9	-4.03	-0.07	-2.52	-0.06	1.82	0.04	1.84	0.03		
M3	0.29	0.02	1.60	0.04	-2.86	-0.06	-3.1	0.06		
A2	-0.21	0.06	0.80	0.18	0.94	0.18	1.28	0.24		
L2	0.70	0.26	1.91	0.40	2.18	0.42	2.46	0.44		
P4	-0.89	0.00	0.48	0.01	0.56	0.02	0.1	0.00		
E5	-2.17	-0.02	-0.70	-0.01	-0.68	-0.02				
L5	-3.37	-0.05	-1.68	-0.03	-1.68	-0.04				
Y5	-3.92	-0.06	-2.13	-0.04	-2.14	-0.04				
N7	-1.54	-0.20	-0.54	-0.10	-0.60	-0.10				
B11	-0.33	0.00	0.55	0.01	0.68	0.00				
F1	-1.14	-0.14	-0.32	-0.05	-0.32	-0.04				
B20	0.18	0.00	1.18	0.01	1.32	0.02				
A19	-0.85	-0.02	0.19	0.03	0.20	0.04				
T2	0.68	0.03	2.04	0.05	2.32	0.04				
A11	-0.81	-0.03	0.06	0.02	0.14	0.02				
S2	0.69	0.26	2.06	0.42						
R5	-4.01	-0.06	-2.21	-0.05						
B4	-0.08	0.01	1.20	0.04						
X8	-2.93	-0.05	-1.70	-0.04						
B3	0.79	0.28	2.07	0.43						
C17	18.32	2.00								
A16	5.06	0.60								
B19	5.92	0.06								
I15	7.43	0.84								
mean	2.37	0.16	1.18	0.08	1.15	0.06	1.44	0.073	1.26	0.045
St Dv	3.33	0.37	0.8	0.12	0.86	0.09	1.175	0.118	0.89	0.065

The same as in latitude case, the number of the used points in the solutions is not equal, so the mean and the standard deviation in each case are computed. Again in the first solution, the four points of network II have the highest residuals. Reducing the used number of points in the solution does not necessarily improves the solution in the case of using equal weights. On the contrary, reducing the number of used points in the solution in the case of using weights improves the solution. Using weights in the solution reduces the residuals of the solution points very much.

The longitude residuals at the five check points are computed from solutions 3, 4, and 5.

Table (5): Longitude residuals at check points from group 1 solutions, units in meters.

Pt.	Solution 3 (25 Pts)		Solution 4 (15 Pts)		Solution 5 (10 Pts)	
	Eq w	W	Eq w	w	Eq w	w
S2	2.37	2.31	2.56	2.58	2.85	2.86
R5	-2.22	-2.25	-3.31	-3.21	1.84	1.77

B4	1.38	1.27	1.32	1.34	2.14	2.15
X8	-1.98	-2.19	-2.13	-2.11	-3.26	-3.26
B3	2.37	2.32	2.57	2.59	2.90	2.91
mean	2.06	2.07	2.38	2.37	2.60	2.59
St Dv	0.41	0.45	0.73	0.69	0.59	0.61

The residuals of both cases are near to each others. The mean values are almost the same. Again at the checkpoints, using weights does not improve the solution.

4.2 Group 2 Solutions

Recalling that, the solutions of group 2 are made to compare between using equal weight coordinates, modified (improved) coordinates, and weighted coordinates in the transformation process. The data used here is the coordinates of 24 available points in the three above mentioned cases. Two solutions of group 2 are computed and their results are obtained.
4.2.1 Solution 6 using the available 24 points

For illustrating their results, the obtained seven parameters in every case are collected in one table for the easiness of comparison.

Table (6): Seven parameters from the three cases of solution 6, using all 24 points.

Parameter	**Using equal weight coord.**	**Using equal weight – modified coord.**	**Using weighted coord.**
DX (m)	-62.543 ± 92.78	-93.127 ± 61.97	-62.561 ± 0.02
DY (m)	167.819 ± 123.76	157.664 ± 71.58	168.112 ± 0.02
DZ (m)	128.524 ± 39.40	115.449 ± 40.39	128.338 ± 0.01
RX (sec)	-1.394 ± 7.418	-2.414 ± 1.143	-1.404 ± 3.770
RY (sec)	-5.049 ± 1.740	-5.838 ± 1.751	-5.047 ± 8.848
RZ (sec)	10.400 ± 3.836	9.940 ± 2.599	10.406 ± 1.946
S	-6.3633 ± 5.343	-1.0440 ± 4.703	-6.3693 ± 2.717

The transformation parameters from the two cases of using equal weights and using weights are close to each others but their standard deviations in the case of using weights are very small compared with their corresponding values from the case of equal weights. The transformation parameters in the case of using improved coordinates are different from those of the other two cases.

Recalling that in the case of using modified coordinates, the following are done. The local coordinates of ESA are subjected to remove process where they are improved. The improved coordinates are used in computing transformation parameters with their corresponding WGS-84 values. The transformed coordinates are obtained and subjected to restore process by adding the removed values. The residuals are then obtained by subtracting the resulted coordinates, through the process (remove – transform – restore), from the original ESA coordinates.

The latitude and longitude residuals are computed at the whole 24 solution points and the results were as follows:

Table (7): latitude and longitude residuals of solution 6 cases at the 24 solution points, units in meters.

	Using equal weight coord.		**Using equal weight – modified coord**		**Using weighted coord.**	
Pt	**Lat res**	**Long res**	**Lat res**	**Long res**	**Lat res**	**Long res**
O1	0.49	-0.05	0.54	0.15	-0.12	-0.00
A2	0.93	1.04	0.38	0.31	-0.39	0.20
L2	1.30	2.15	0.19	0.54	0.30	0.44
A3	1.49	2.37	0.16	0.52	0.34	0.07
M3	0.96	1.90	-0.05	0.60	0.05	0.04
A4	-0.77	0.71	-0.98	-0.60	-0.40	0.14
P4	-1.03	0.72	-0.50	0.66	0.09	0.01
E5	-0.84	-0.53	-0.50	-0.25	0.15	-0.01
L5	0.17	-1.62	-0.11	-0.61	0.21	-0.03
O5	0.40	-1.90	0.06	-0.57	0.18	-0.04
Q5	0.37	-2.10	-0.05	-0.66	-1.86	-0.06
A5	-0.88	0.50	-0.70	0.27	0.01	0.01
Y5	0.32	-2.14	0.03	-0.71	0.26	-0.04
F6	0.52	-0.13	0.61	0.13	-0.15	0.00
E7	-0.07	0.24	0.46	1.19	-0.03	0.00
A6	0.69	1.14	0.90	0.39	-0.13	0.02
N7	-0.96	-0.44	0.02	-0.26	-0.08	-0.08
D8	-1.22	-1.27	-0.02	-0.72	0.02	0.02
Z9	-3.38	-2.58	-1.81	-0.49	0.03	-0.05
S2	1.56	2.31	0.20	0.48	0.62	0.46
R5	0.34	-2.23	0.06	-0.76	0.27	-0.04
B3	1.67	2.34	0.37	0.72	0.54	0.46
B4	0.02	1.51	-0.36	0.29	0.07	0.04
X8	-2.34	-1.77	-0.96	-0.41	0.00	-0.04
mean	0.95	1.4	0.42	0.67	0.26	0.10
St Dv	0.58	0.67	0.18	0.59	0.14	0.02

The least latitude and longitude residuals at the solution points are produced from the weighted solution. The mean value of latitude and longitude in the case of the improved coordinates solution is almost half its corresponding value in the case of using equal weights. The three solutions are done using all the available 24 points of this group, so there are no points for checking the solutions.

4.2.2 Solution 7 Using 19 Solution Points and 5 Check Points

Solution 7 used 19 points in the solution and excluded 5 points for checking the solution. The transformation parameters are computed in every case and they were as follows:

Table (8): Seven parameters from the three cases of solution 7, using 19 points.

Parameter	**Using equal weights**	**Using equal weights – modified coord.**	**Using weighted coord.**
DX (m)	89.076 ± 76.47	-118.743 ± 76.08	-88.832 ± 0.02
DY (m)	186.685 ± 90.25	175.863 ± 89.79	186.714 ± 0.03
DZ (m)	152.199 ± 48.35	138.827 ± 48.11	151.82 ± 0.01
RX (sec)	-1.296 ± 1.453	-2.329 ± 1.446	-1.305 ± 2.21
RY (sec)	-6.012 ± 2.106	-6.787 ± 2.095	-6.001 ± 1.01
RZ (sec)	11.280 ± 3.256	10.7774 ± 3.240	11.276 ± 1.57
S	-6.4099 ± 5.848	-1.1350 ± 5.819	-6.413 ± 1.84

Again the transformation parameters from the two cases of using equal weights and using weights are close to each others but their standard deviations in the case of using weights are very small compared with their corresponding values from the case of equal weights. The transformation parameters in the case of using improved coordinates are different from those of the other two cases.

The latitude and longitude residuals are computed at the 19 solution points and the results were as follows:

Table (9): latitude and longitude residuals of solution 7 cases at the 19 solution points, units in meters.

	Using equal weight coord.		**Using equal weight – modified coord**		**Using weighted coord.**	
Pt	Lat res	Long res	Lat res	Long res	Lat res	Long res
O1	0.54	0.04	0.51	0.19	0.01	0.00
A2	0.97	1.16	0.34	0.37	0.02	0.24
L2	1.33	2.30	0.15	0.61	0.24	0.46
A3	1.55	2.54	0.13	0.61	0.04	0.08
M3	1.04	2.07	-0.08	0.66	0.02	0.04
A4	-0.69	0.87	-0.17	0.57	-0.12	0.17

P4	-0.92	0.86	-0.51	0.67	-0.02	0.02
E5	-0.71	-0.41	-0.50	-0.26	-0.01	-0.01
L5	0.36	-1.49	-0.05	-0.62	0.01	-0.03
O5	0.59	-1.80	0.15	-0.59	0.01	-0.04
Q5	0.58	-1.96	0.05	-0.68	0.02	-0.06
A5	-0.78	0.63	-0.71	0.28	-0.01	0.01
Y5	0.54	-2.01	0.12	-0.73	0.01	-0.04
F6	0.58	-0.05	0.59	0.16	0.02	0.00
E7	-0.04	0.33	0.41	1.22	0.00	0.01
A6	0.79	1.23	0.90	0.45	0.02	0.03
N7	-0.97	-0.38	-0.04	-0.25	-0.17	-0.07
D8	-1.28	-1.25	-0.12	-0.75	-0.02	-0.03
Z9	-3.68	-2.55	-2.12	-0.53	-0.07	-0.06
mean	0.94	1.26	0.40	0.54	0.04	0.07
St Dv	0.75	0.83	0.49	0.25	0.06	0.11

The least latitude and longitude residuals at the solution points are produced from the weighted solution. The mean value of latitude and longitude in the case of the improved coordinates solution is less than half its corresponding value in the case of using equal weights. The latitude and longitude residuals at the 5 check points are computed and they were as follows:

Table (10): Latitude and longitude residuals at 5 check points from solution 7 cases, units in meters.

Pt.	**Using equal weight coord.**		**Using equal weight – modified coord**		**Using weighted coord.**	
	Lat. res	**Long. res**	**Lat. res**	**Lat. res**	**Long. res**	**Lat. res**
S2	1.56	2.70	0.15	0.57	1.57	2.72
R5	0.55	-2.20	0.15	-0.78	0.54	-2.19
B4	1.68	2.74	0.34	0.80	1.68	2.75
X8	0.10	1.80	-0.39	0.35	0.10	1.81
B3	-2.45	-2.00	-1.16	-0.48	-2.44	-1.97
mean	1.27	2.29	0.43	0.60	1.26	2.29
St Dv	0.94	0.42	0.42	1.2	0.94	0.43

At the used check points, the two cases of using equal weights and using weights have almost identical residuals. The mean value of the latitude residuals in the case of using the improved coordinates is third of its corresponding value in the other two cases. While the mean value of the longitude residuals in the case of using the improved coordinates is fourth of its corresponding value in the other two cases.

5. CONCLUSIONS

Two main subjects are investigated in this research. The first one was studying the effect of using weighted coordinates in the transformation process. The computations are done using 34 common points with different weights and 5 solutions were made. Using weights improved the precision of the transformation parameters and improved also the residuals of the solution points significantly. In the same time, using weights did not improve the residuals at the check points and the residuals at those check points were almost the same as in the case of using equal weighted coordinates. The second subject of this research was studying the effect of using adjusted coordinates in the transformation process while keeping the resulted transformed coordinates in ESA system of coordinates. The transformation process was done in more accurate atmosphere, so the obtained latitude residuals were third their corresponding values in the case of using ESA coordinates. The obtained longitude residuals were fourth their corresponding values in the case of using ESA coordinates. This process is named here (remove – transform – restore).

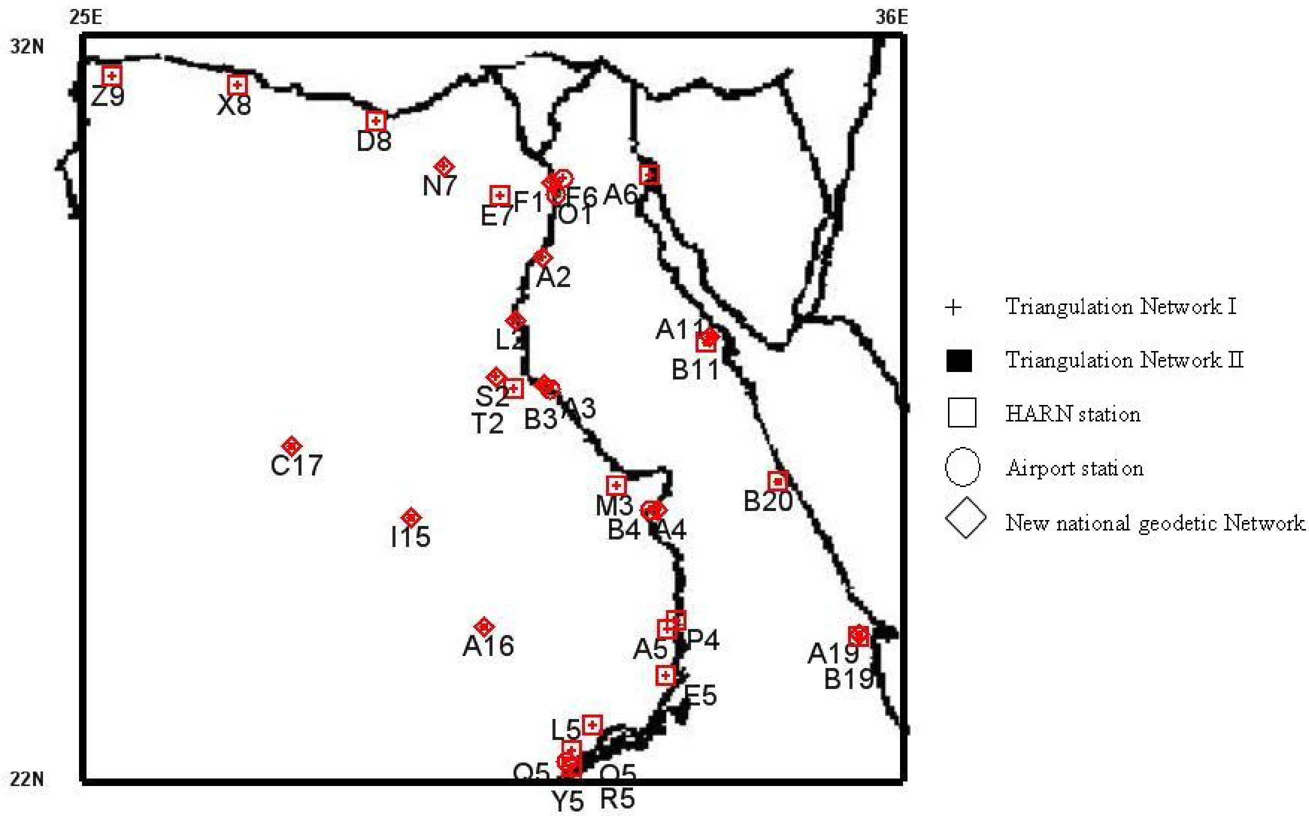

Fig. 1: Common points used in the computations of Group 1 solutions.

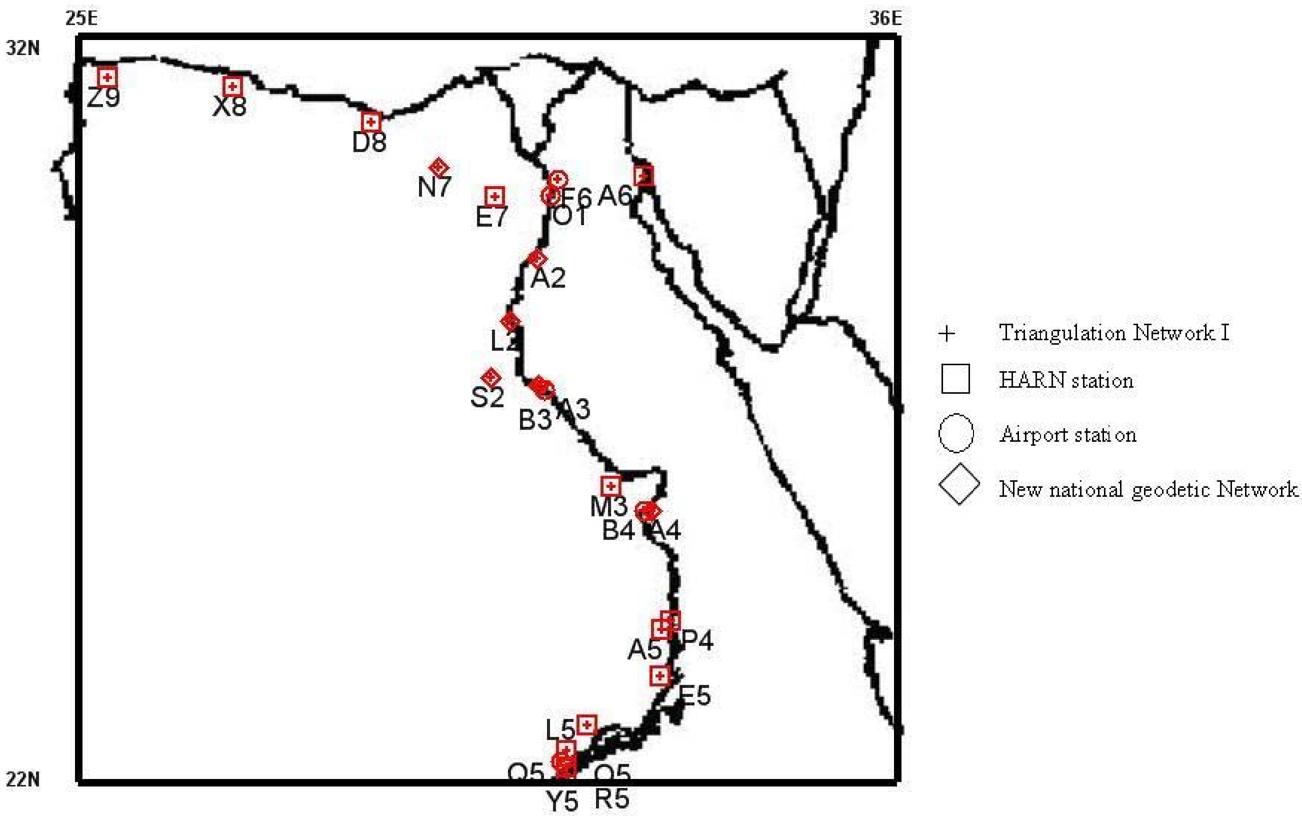

Fig. 2: Common points used in the computations of Group 2 solutions.

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