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EFFICIENCY OF NEW SOLUTIONS FOR SURVEYING AND MAPPING PROBLEMS IN INTEGRATED WATER RESOURCES MANAGEMENT

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ABSTRACT

Maps play a vital role in the overall framework of the undergoing integrated water resources management in Egypt. Satellite-based technologies, especially GPS, have been utilized exclusively in the last two decades as positional data collection tools for a wide variety of water resources national applications. Neglecting the complicated geodetic datum transformation computational process, the collected positions will be biased by approximately 150 meters horizontally.

Instead of the mathematically complicated conventional approach, a new simple technique is derived. Two regression formulas and two conversion surfaces have been developed to convert GPS coordinates. The efficiency of this model is investigated for hydrographic surveying, as a candidate of water resources management applications. Control networks cover 203 Km, over the second reach of the river Nile, has been used to examine the new scheme. It has been found that this method produces improvements in positional accuracy by approximately 22 %. Simplicity and ease-of-use, even in the field, are the main merits of the developed system. Such a technique solves one of the main difficulties in surveying and mapping applications in an economical manner.

1. INTRODUCTION

Acquisition of accurate and up-to-date topographic and hydrographic maps is a key element in the context of water resources management. It is a matter of reality that the Egyptian mapping system, as established by the Egyptian Survey Authority (ESA), has been built based on a specific geodetic datum. This national datum, called the Old Egyptian Datum (OED), has been designed related to the Helmert 1906 ellipsoid. That ellipsoid was the best mathematical surface representing the figure of the Earth in the beginning of the twentieth century. Each country has its own mapping system referenced to a specific ellipsoid. Although many other ellipsoid have been defined worldwide over that long time, the process of changing the entire mapping system is too expensive and time consuming to be carried out.

The Satellite-based Global Positioning System (GPS) is the current most precise and widely used positioning technology worldwide. As a positional data collection tool, GPS has been utilized in water resources management applications [e.g. 1 and 3]. However, the GPS-derived coordinates are referenced to a global geodetic datum called World Geodetic Datum 1984 (WGS84). Hence, GPS data have to be transformed from that global datum to the national Egyptian one. Neglecting this datum transformation computational process, the collected positions will be biased by approximately 150 meters horizontally. With the rapid growth of GPS utilization, the issue of datum transformation becomes a great concern of the surveying and mapping community [e.g. 6]. Several conventional models for datum transformation have been proposed and utilized since 1960's. Most of these traditional approaches are complicated, in a mathematical sense, and require a lot of field and data processing steps. A new simple approach based on multiple regression or conversion surfaces has been proposed lately [2]. This paper aims to develop and investigate the utilization of a similar technique to solve the datum transformation issue in water resources mapping projects.

2. TRADITIONAL DATUM TRANSFORMATION MODELS

Traditionally, the similarity datum transformation models have been introduced and utilized in geodetic applications since the sixties. This type of datum transformation has gained a great focus since it has a geometrical interpretation of the determined parameters. A similarity transformation model is based on 7 parameters: three translation parameters (dX, dY, and dZ), three rotation parameters ($\omega_{x,}$ $\omega_{y,}$ and ω_z); and a parameter (s) for the scale difference between the two coordinate systems. There are many similarity transformation models, e.g. Bursa-Wolf model, Molodensky-

Badekas model, Veis model, and Vanicek and Wells model. It is not an objective of the current paper to present the complicated mathematical formulation that defines each model. Details concerning these models are found in various literatures [e.g. 4].

3. UNCONVENTIONAL DATUM TRANSFORMATION APPROACH

Dawod and Alnaggar [2] have utilized the stepwise multiple regression technique for datum transformation determination for two basic reasons: the need for better accuracy than could be achieved through the similarity datum transformation formulas; and the need for a technique more manageable for field use. This technique is based on modeling the differences ($\Delta\phi$ and $\Delta\lambda$) between the geodetic coordinates of two systems by two polynomials in order to spatially represent the differences over the network, to a given degree of accuracy. They have found that, over the Egyptian territories, the differences in latitude range from 0.2104“ to 0.8654” with an average of 0.4678”, while the differences in longitude range from 5.8129“ to 6.0897”. Similar methods have been proposed and applied worldwide in several surveying applications [e.g. 7].

The same principle has been utilized in this research study with slight modifications for seek of simplicity. The developed conversion formulas, for transforming coordinates from the WGS84 to the OED systems are:

$$\Delta\phi'' = a_o - a_1\,\phi_{84} + a_2\,\lambda_{84} \quad (1)$$

$$\Delta\lambda'' = b_o + b_1\,\phi_{84} + b_2\,\lambda_{84} \quad (2)$$

where:

$\Delta\phi$ and $\Delta\lambda$ are obtained in arc of seconds,
a_o , a_1 , a_2 , b_o , b_1 , and b_2 are the unknown parameters to be estimated,
ϕ_{84} and λ_{84} are the WGS84 latitude and longitude coordinates in degrees.

Therefore, the transformed coordinates on the OED coordinate system are given by:

$$\phi_{OED} = \phi_{84} + \Delta\phi \quad (3)$$

$$\lambda_{OED} = \lambda_{84} + \Delta\lambda \quad (4)$$

4. AVAILABLE DATA

The utilized data consists of a geodetic control network established by NRI in 1995. The objective of this network was to support hydrographic and land surveying activities in the Esna – Nag Hammadi reach (Figure 1). That network consisted of 82 horizontal control points covering the distance between upstream Esna barrage by approximately 10 Km to Nag Hammadi barrage, with a total distance of 203 Km (Figure 2). Another two stations, A4 and B4 from the national horizontal control networks, have been observed too in order to tie the network to the national mapping system of Egypt. The network covered both banks of the Nile with a distance separation of almost 5 Km apart. GPS geodetic high-precision receivers have been utilized to observe the network in a static (network) mode. Each field observation session contained four points, and continued for at least one hour. In some cases, the session time was extended to three hours for quality control purposes over large sections of the entire network [NRI, 1996].

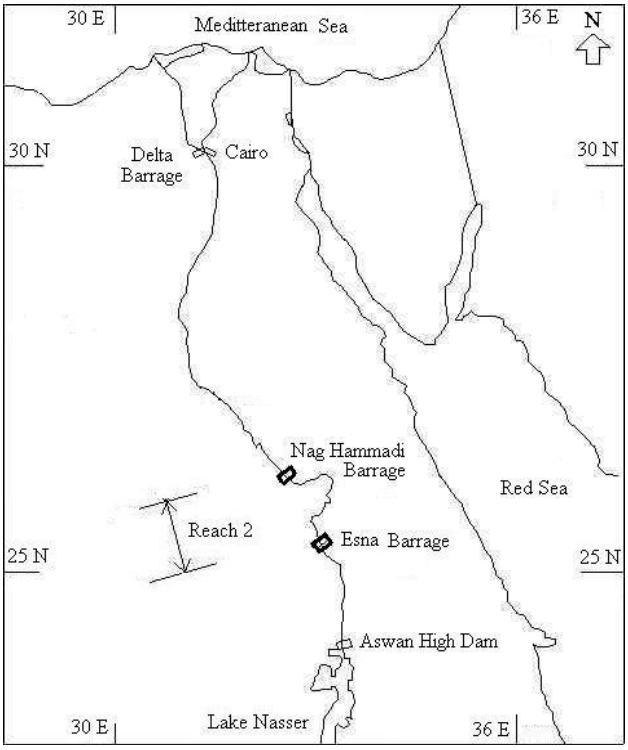

Figure 1: The study area

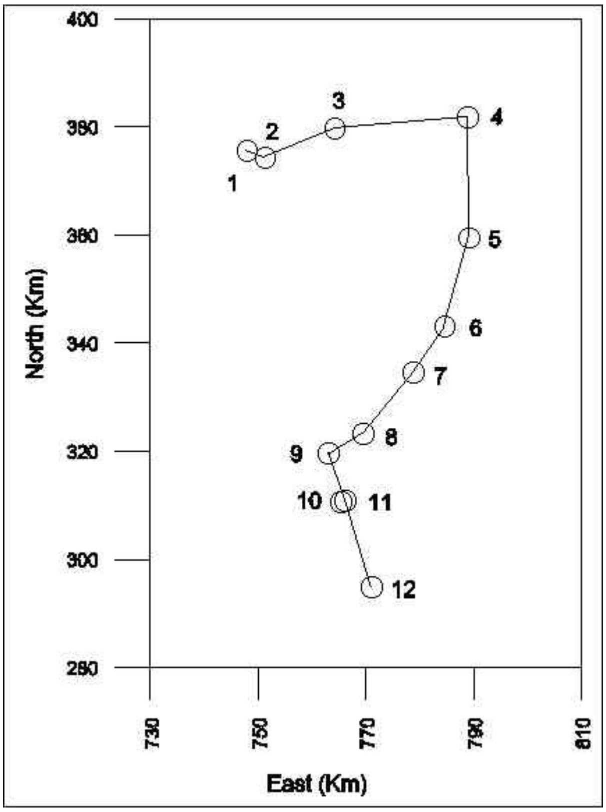

Figure 2: The utilized GPS Network

5. OBTAINED RESULTS

The available control network has been utilized in testing and comparing the two approaches of geodetic transformation. The following sub-sections document the obtained results.

5.1 Results of traditional geodetic transformation approach

Based on field reconnaissance, it has been found that twelve stations of that network belong to the Kenting control network established over the Nile in the period from 1978 to 1982. Those stations have been found in good and trustable conditions. They have known coordinates on the Old Egyptian Datum of 1906, simply known as OED. Based on the collected static GPS observations, coordinates on the WGS84 global geodetic datum are computed for these stations. Having known coordinates of these stations on both geodetic datums, traditional geodetic datum transformation parameters have been determined using the Molodensky-Badekas model. Four control stations (No. 1, 4, 6, and 12) have been utilized to come up with the transformation parameters presented in Table 1 [5]. In order to check the accuracy of the transformation set, OED coordinates have been computed, using equations 3 and 4, and compared against the known (true) values for the remaining eight points. In order to visualize the error estimates in a simple view, they have been computed on the two-dimensional mapping coordinate system (Easting and Northing coordinates). Table 2 gives the error values of this approach over the check points. From this table it can be seen that the errors in the east direction range from -1.4 m to 0.98 m, while the errors in the north direction vary from -0.58 m to 0.76 m. Additionally, these error figures have been translated to the corresponding linear (distance) error for each station. Linear errors rang from 0.44 m to 1.59 m, with an average value of 0.83 m.

Table 1: Results of traditional datum transformation method

Parameter		Value
Shift dX	(m)	136.669
Shift dY	(m)	-118.399
Shift dZ	(m)	37.546
Rotation about X axis	(“)	41.871628
Rotation about Y axis	(“)	1.446345
Rotation about Z axis	(“)	31.253743
Scale factor	(part per million: ppm)	169.902065

Table 2: Errors of traditional datum transformation method (m)

Error in Easting	Error in Northing	Linear Error
0.98	0.74	1.23
-0.50	-0.58	0.76
-0.38	-0.37	0.53
-0.39	-0.56	0.68
0.24	-0.48	0.54
-0.87	0.23	0.90
-0.08	0.43	0.44
-1.40	0.76	1.59

5.2 Results of new geodetic transformation approach

The same four control stations have been used to solve the regression formulas 1 and 2, and estimate the unknown parameters. The final obtained regression equations are:

$$\Delta\phi'' = -0.1394996 - 0.0376027\,\phi_{84} + 0.0432308\,\lambda_{84} \quad (5)$$

$$\Delta\lambda'' = -3.8239521 - 0.0519775\,\phi_{84} - 0.0324810\,\lambda_{84} \quad (6)$$

In order to judge the accuracy of the model, errors have been computed for the remaining eight stations. Table 3 presents the values of these errors. From this table it can be seen that the errors in the east direction range from -1.12 m to 0.78 m, while the errors in the north direction vary from -0.57 m to 0.74 m. Additionally, these error figures have been translated to the corresponding linear (distance) error for each station. Linear errors rang from 0.38 m to 1.32 m, with an average of 0.69 m.

The differences in latitude, between the WGS84 and the OED datums, have a minimum of 0.278" and a maximum of 0.315", with a mean value of 0.298". The corresponding differences in longitude vary from -6.245"to -6.198", with an average equals -6.221". Figures 3 and 4 depict contour maps for these differences, which can be considered as conversion surfaces between both geodetic datums.

Table 3: Errors of new datum transformation method (m)

Error in Easting	Error in Northing	Linear Error
0.78	0.74	1.08
-0.05	-0.57	0.58
-0.33	-0.26	0.42
-0.51	-0.26	0.57
0.21	-0.37	0.43
-0.71	0.23	0.75
-0.08	0.37	0.38
-1.23	0.70	1.32

5.3 A comparison of results

Comparing the obtained results from both datum transformation approaches, it can be seen that the second one is optimum. In terms of accuracy, the conversion surface method produces improvements in positional accuracy that is approximately 21.7 %. However, the second technique is trouble-free and can be used quickly even by means of a calculator. There is no need to utilize a sophisticated computer programs to convert GPS positions to the national mapping system. Moreover, the achieved conversion surfaces, figures 3 and 4, can also be used to interpolate the differences between both datums in an effortless manner. Hence, this approach is appropriate for almost all applications in water resources management.

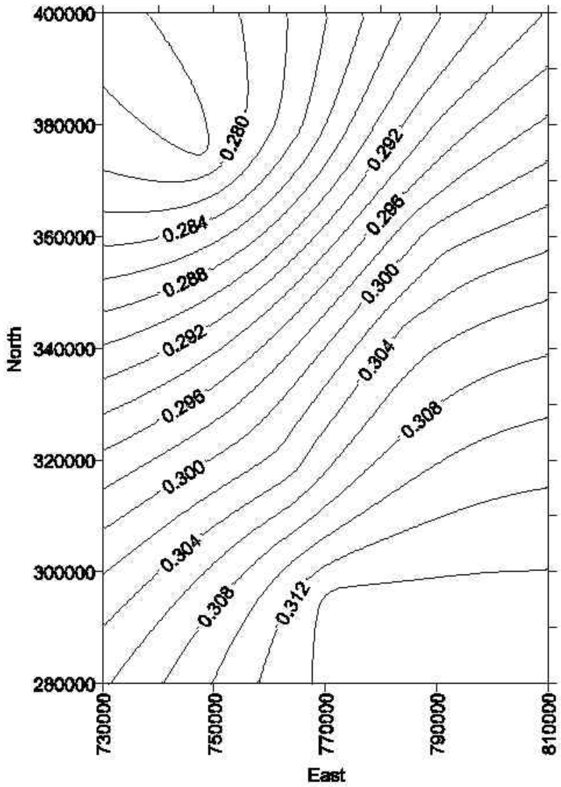

Figure 3 : Latitude conversion surface

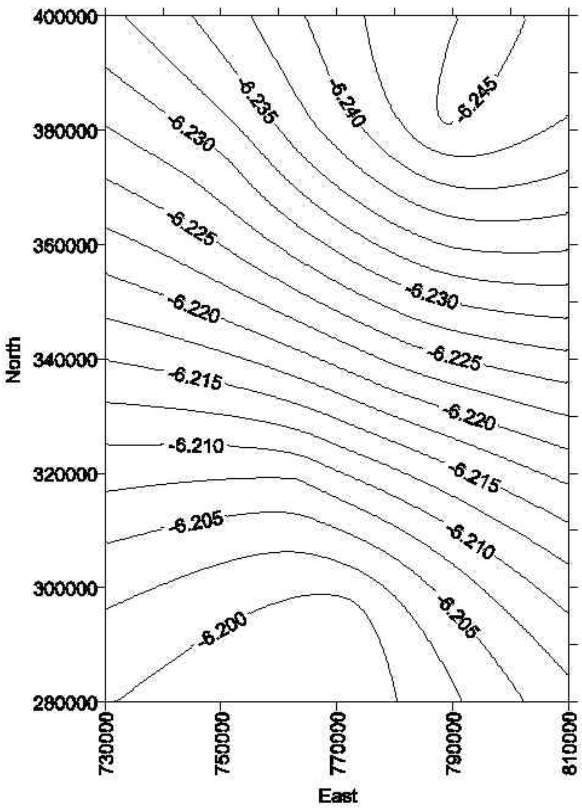

Figure 4: Longitude conversion surface

6. CONCLUSIONS

Recently, the GPS satellite technology has been employed widely in integrated water resources management projects as a positional data collection tool. Hence, the issue of converting GPS data to the Egyptian national mapping system becomes a fundamental significance. Instead of the mathematically complicated similarity transformation approach, a new simple technique is derived and investigated. Two regression formulas and two conversion surfaces have been developed for the second reach of the Nile, extending 203 Km, to convert GPS coordinates. It has been found that this method produces improvements in positional accuracy by approximately 22 %. Moreover, it is an effortless procedure, that can be used quickly even by means of a calculator. Additionally, the achieved conversion surfaces can also be used to interpolate the differences between both datums in a straightforward manner. So, the developed scheme is proper for mapping applications in the integrated water resources management process in Egypt. It is recommended that the same procedure is employed for the other reaches of the Nile and its two branches.

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