Terrain Creation and Analysis Using Information from GPS and Classical Techniques

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SUMMARY

A Digital Terrain Model (DTM) in the broader area of a village (Metalliko) at the Northern part of Greece has been created using GPS and spirit leveling data and compared with existing terrain information from the Hellenic Military Geographical Service in terms of equidistant topographical maps for the same area, that were produced from conventional photogrammetrical techniques. Rapid static surveys with dense elevation data were used for the determination of the local geoid transformation parameters. Dense elevation data has been acquired using kinematic GPS leveling traverses for landscape creation. Useful results for the applied techniques, the terrain features and the achieved accuracies are drawn and discussed.

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1. INTRODUCTION

A wide range of applications is now driving the requirements for increased detail in Digital Terrain Models (DTM). Detail in this instance is defined by the horizontal sample spacing and vertical accuracy of the measurement. Main motivation of the present study was to investigate the possibilities of assessing the accuracy and overall quality of digital terrain models, especially as terrain databases of constantly growing resolution are becoming available both globally and regionally. Most of the current digital terrain models are the product of survey methods or photogrammetric data capture. These sources rely on the stereoscopic interpretation of aerial photographs or satellite imagery using manual or digital stereoplotters. In this study, we restrict ourselves to test the accuracy of the existing reference DTMs for the area of Greece, produced in the 1970s by the Hellenic Military Geographical Service, with classical photogrammetric techniques. In order to do so we compare these maps, after we have transformed them into a digital form through a standard digitizing procedure, with DTMs which can be derived from other sources, such as ground measurements, using GPS and spirit leveling. As the elevation maps of the HMGS are the only available terrain information for the majority of the Hellenic area, obtaining a measure for their accuracy would be of critical importance for many relevant applications in the future. A successful evaluation and knowledge of the "truth" is particularly important for organizations, both public and private, involved in production or in several engineering studies. Our results support the idea that using both GPS and a local geoid solution we can produce and compare DTMs, in order to have an estimation of the final accuracy in areas of various relief or vegetation, forests, etc. These physical parameters can seriously affect the nominal accuracy, especially after long periods.

2. STUDY AREA AND GPS CAMPAIGN

The test area is located in the northern part of Greece, in a local area of Kilkis prefecture (fig. 1), around a village called Metalliko, with a 190-m. mean elevation above sea level. The test area can be characterized mainly by the open horizon to GPS signals without buildings and this was the main reason for its selection. The area, were the GPS measurements took place and was thus considered for the DTM comparisons that are presented in the sequel, extends finally to 800 m in the East-West and 1000 m in the North-South direction, being situated approximately 45 Km northwest from Thessaloniki.

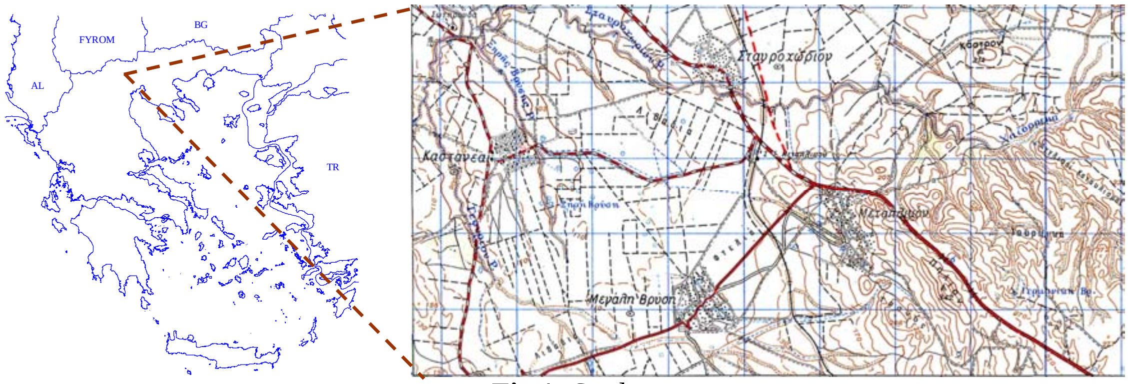

Fig 1: Study area

2.1 GPS measurements

The first aim of this study was the determination of the local geoid solution, in order to transform the GPS-derived ellipsoidal heights to orthometric heights referring to the National Vertical Reference System (NVRS). For this reason, a total number of 30 GPS/leveling benchmarks were measured in the test area. The measured points derived from three sets. The first set was part of the National Vertical Reference System, the second set was established with individual leveling traverses between the points of the first set and the last set was triangulation pillars of the National Horizontal Geodetic Network with their orthometric heights relevant to NVRS (Rossikopoulos 1999, Pikridas et. al., 2002). The measurements were performed in static mode using two sets of Leica dual frequency receivers System 500. In all sessions the observation duration was at least 40 minutes with a recording interval of 15 sec. and the baselines between reference and rover were all less than 10 Km. All baseline ambiguities were successfully fixed to their integer values.

The geoid undulations were computed fitting a plane model (bias and tilt) to the differences between the ellipsoidal heights provided by GPS and the orthometric ones from the leveling surveys according to the following formula: $h_i - H_i = a_0 + \alpha_1 x_i + \alpha_2 y_i$.
The determined model parameters are given in Table 1.

Table 1: Plane parameters for the computation of the local geoid undulations

Parameter	Value	Comments
a_0	42.65160 (in m)	
a_1	0.00034 (in deg)	Inclination of height in X
a_2	0.00017 (in deg)	Inclination of height in Y

Accuracy from 0.02 to 7 cm in orthometric height was achieved after the transformation with a 2.6 cm of mean transformation accuracy. These values reflect the best surface selection to describe the geoid heights. We must point out, that this result was expected, due to the overall smooth topography of the test area. The residuals of the GPS/benchmarks after the transformation are presented in table 2.

Table 2: Height residuals on GPS benchmarks (after bias and tilt)

Point Number	Residuals (cm)	Point Number	Residuals (cm)
1	1.68	16	4.29
2	2.86	17	0.31
3	1.00	18	1.25
4	3.35	19	0.70
5	1.10	20	0.29
6	2.26	21	0.03
7	0.84	22	0.02
8	2.82	23	6.69
9	0.02	24	5.60
10	0.32	25	1.98
11	1.00	26	0.67
12	0.51	27	4.23
13	0.12	28	0.35
14	3.33	29	1.99
15	1.81	30	4.96

The GPS leveling traverses were realized using the Stop and Go technique. With this positioning method an accuracy of a few centimeters is usually obtained (Fotiou and Pikridas 2002). Three Leica dual frequency receivers were placed each one on a pole and a five seconds (5 sec) recording interval was selected. The point spacing was selected at about 20-25 meters and the time remaining at every point was 40 seconds (eight epochs). A reference receiver was placed near the test field, therefore the maximum baseline length for every point of each kinematic chain didn't exceed 2 Km. In all observing sessions the GDOP value varied between 3-6 where as the SNR values for almost all satellites were at their maximum. Finally, a number of 1020 points were recorded, with the kinematic campaign lasting four days with eight hours of measurements within each day.

In order to check the accuracy between the different kinematic sessions many cross points were occupied. All the results and the analysis of GPS data in this study have been carried out using the skipro v.2.5 software of Leica.

3. DIGITAL TERRAIN MODEL INFORMATION

The information of a derived DTM can greatly vary depending on the source data and the interpolation technique. The desired quality depends on the application for which the DTM is to be used, but a DTM created for one application is often used for other purposes as well. Our reference DTM was obtained from the Hellenic Military Geographical Service (HMGS) and was produced using analytical photogrammetrical techniques in 1978. The quality of the elevation data is which derived from these topographic maps (scale 1:5000) depends on the quality of the map itself. The contour interval of the reference map was 2 m with elevation accuracy of about 1m (fig. 2). These kind of DTM's are usually available from public mapping agencies.

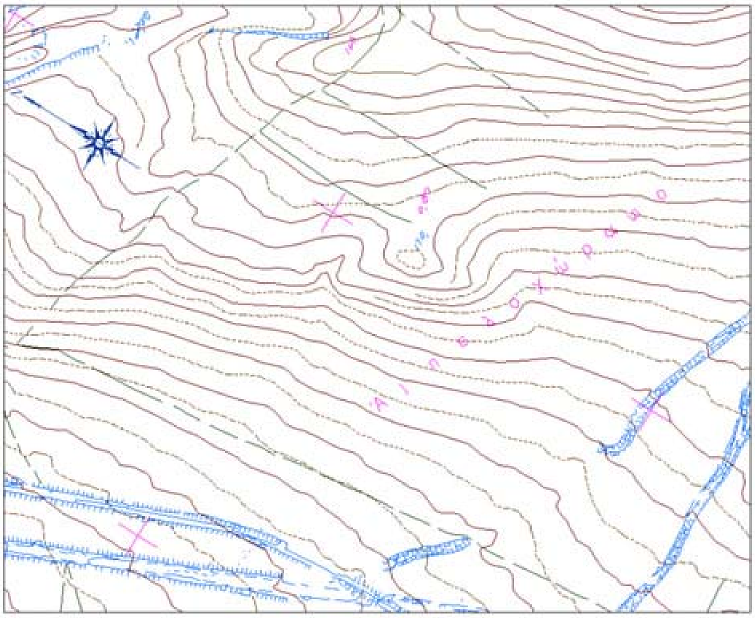

Fig 2: DTM derived from classical measurements

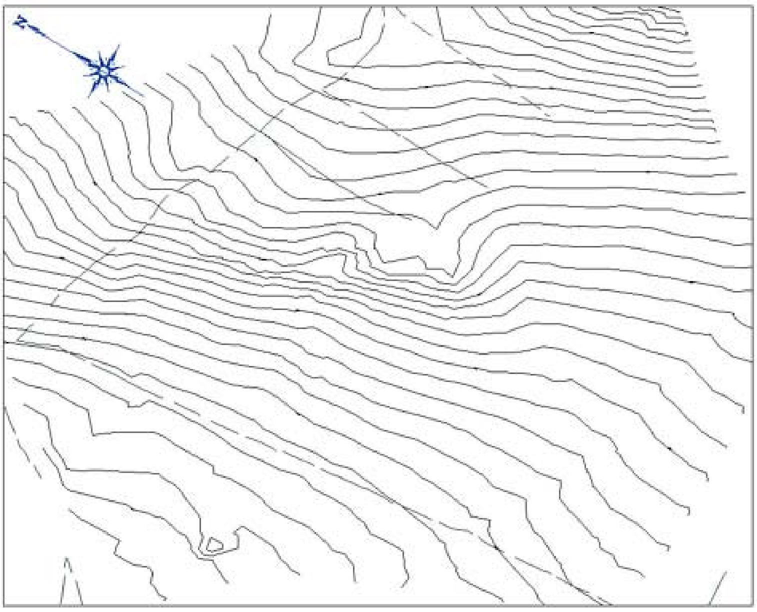

Fig 3: DTM obtained from GPS measurements for the same area

Figure 3 shows a contour plot of the respective DTM for the same area, based on the GPS data and the preliminary geoid model which were discussed in the previous section.

The similarity of the two DTMs even in representing detailed terrain features is obvious as figure 4 clearly demonstrates. Considering that a period of 25 years has passed between the two determinations, we can say that the results are of a pretty good quality.

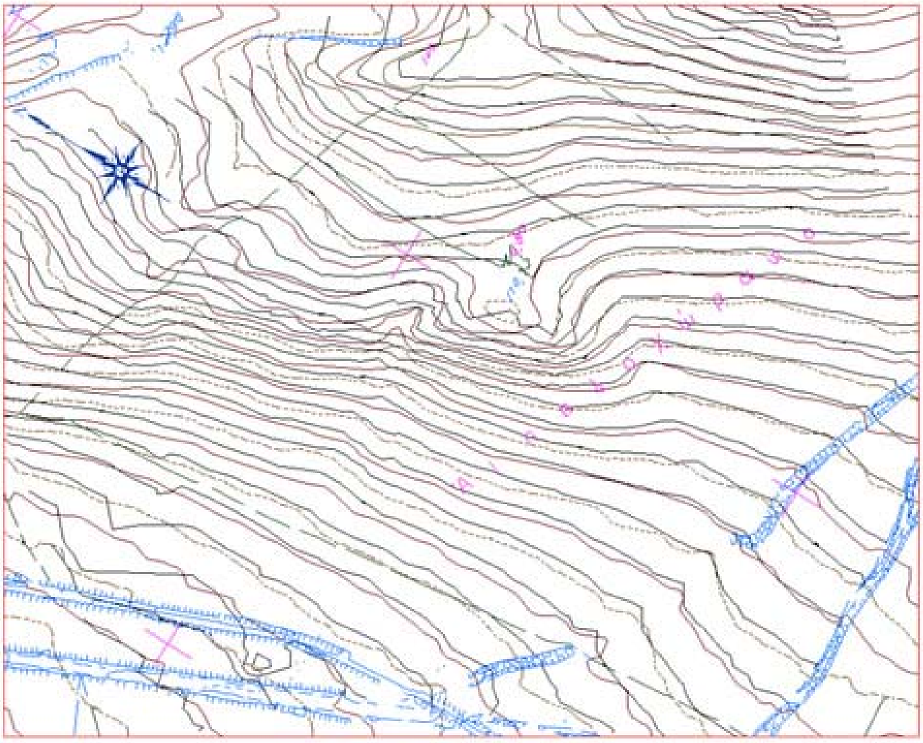

Fig 4: The two DTMs for the test area: a) obtained from GPS measurements (with black solid lines) b) derived from classical measurements (color lines).

The assessment of elevation differences between both, the reference and the GPS and geoid derived data set was based on comparisons, the basis of the comparative study. Elevation differences were calculated on cross points between contour lines (of the reference DTM) and GPS leveling traverses. Figures 5 and 6 depict the calculated differences according to elevation values, where it is obvious that no systematic behaviour can be detected. The differences between the reference DTM and the GPS-based DTM along a selected West-East profile vary between +40 cm and –60 cm having an absolute mean value of (approximately) 20 cm. The overall displacements of the contour lines between the two DTMs are mainly due to datum compatibility problems and to the interpolation techniques used.

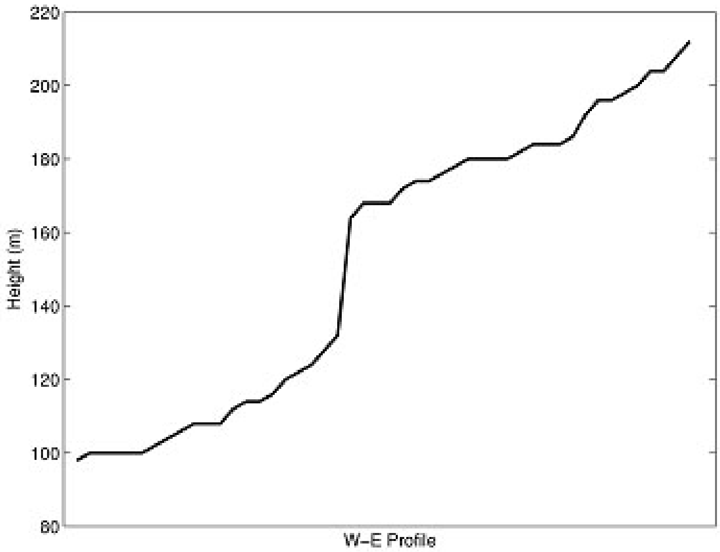

Fig 5: Elevation profile of selected differences for the two DTMs

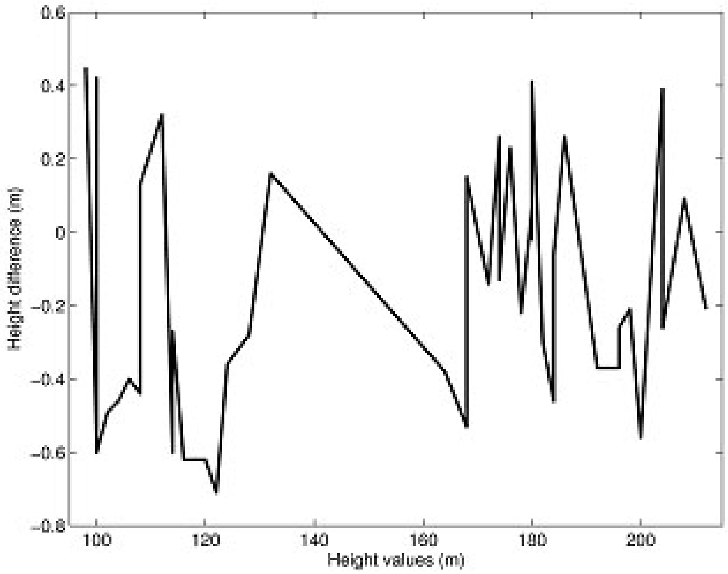

Fig 6: Height differences according to elevation values

4. CONCLUSIONS

Elevation data are a very sufficient data source for many engineering applications since they can be used for a long time and represent the landscape of the study area. Our comparisons showed differences from few centimeters (2 cm) up to 70 cm for two heterogeneously DTM's the one obtained from digitizing a 1:5000 contour map of the Hellenic MGS, which served as the reference DTM for our study, the other being calculated from about 1000 GPS Stop and Go stations spread over the same area, combined with a preliminary geoid model. The magnitude of the obtained differences can be considered as realistic, keeping in mind that the changes in landscape in a period of 25 years could be greater than these values, due to farming activities, constructions etc. The reference DTM shows a sufficient reliability in case we are interested in accuracies of the order of one meter.

The combination of GPS and a local geoid prove to be a very efficient method of aquaring data with few centimeters accuracy in order to produce a reliable DTM, but it requires fieldwork for capturing detailed terrain features.

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