INVESTIGATON ON THE ACCURACY OF DIGITAL ELEVATION MODELS (DEMs) USED IN PRODUCING ORTHOPHOTO MAPS IN THE MARMARA EARTHQUAKE AREA

Mahmut ÖZBALMUMCU
Dr.Lt.Col.
Photogrammetry Department
The Chief of The Digital Map Compilation Section
e-mail : mozbalmumcu@hgk.mil.tr.
TR 06100   Cebeci-Ankara / TURKEY

KEY WORDS : Digital Elevation Model (DEM), TIN, Ortho-rectification, Digital Instrument, Automatic DEM Production.

ABSTRACT

The accuracy of Digital Elevation Model (DEM) data is one of the most important point which effects the precision of the final orthophotos. DEM data has been commonly used for both ortho-rectification of aerial photographs and for generation of contour lines of the land surface. Besides the accuracy and density of the data, investigations for the most appropriate data collection method of DEM representing the land surface are still being carried out for many years. The advence of the digital photogrammetric systems made it possible to collect the DEM data full-automatically. But, it is understood that the DEM data produced full-automatically by the digital instruments which might have some problems in places like forestry and urban areas, swamps, low contrast areas and trees, were not compatible with the ground surface and, for that reason, it could be required to make intense editing works on the stereo models. Although the DEM data collected manually, semi-automatically or full-automatically is eliminated from errors and represents the land surface very well, it is often encountered with some problems especially in the production of contour lines.

Another method for producing DEM data is to extract the data at the regular grid structure or to get TIN data with the irregular height points with specific density from the digital contours by the photogrammetric or cartographic methods in 3-dimensional.

In the areas effected from the earthquake, there are various kinds of topographical structures such as coastal regions, forestry areas, vineyards, orchards, roughy grounds, plant areas. For that reason, it is rather difficult to apply a standard technique for the production of the DEM data and contour lines necessary for the orthophoto maps.

The main purpose of this paper is to determine the appropriate method in the production of DEM data and contour lines required for producing orthophoto maps in the earthquake area and to investigate the accuracies of the final results obtained from the different methods.

1 INTRODUCTION

In Photogrammetry Department of General Command of Mapping, approximately 1300 sheets of 1:5.000 scaled orthophoto maps have been produced in order to determine the damages of the Marmara Earthquake occurred on the north-west part of Turkey, and to use them in general planning, region and city planning and rebuilding the new urban areas.

The basic elements necessary for producing orthophoto maps from aerial photographs at different scales are aerial photographs taken with an appropriate scale, ground control points with a proper density and number, and Digital Elevation Model (DEM) data having enough precision and density (Krauss, 1993).

The DEM data, having the acceptable error limits and used for only orthophoto production, doesn' t have much effects on the accuracy of the final orthophoto maps. But, it is well known that, the accuracy of the DEM data has very much effects on the production of contour lines of the land surface; some small errors in the DEM data may cause big errors on the production of the contour lines; If the DEM data with enough density and accuracy couldn' t be used, the contour lines produced from DEM may not to be able to reflect the topographical structure of the ground surface correctly (Ackermann, 1995).

There are two different methods generally used for the production of contour lines of the land surface in the orthophoto and vector maps. In the first method; the contour lines are produced full-automatically by the generation technique from the DEM data produced in advance. In the second method; the contour lines are directly produced in 3-dimension by digitisation of the stereo models formed in the stereo photogrammetric instruments such as analog, analytical, computer-supported analog (semi analog-semi analytical) and digital instruments (Fritsch, 1997).

There are mainly two different approaches frequently used for the production of DEM data. In the first approach; DEM data having enough accuracy and density and which are compatible with the photo and orthophoto scale to be produced, are collected manually or semi-automatically in the analog, computer-supported analog and analytical instruments; they are full-automatically collected in the digital photogrammetric instruments. In the second approach; DEM data with a specific density and in a regular grid form, and TIN data is extracted from the digital contour lines produced by the photogrammetric or cartographic methods in advance. There are various ways on the collection of DEM or TIN data by using existing digital contour lines. The elevation data mentioned above can be produced by using work/stations (W/S), personnel computers (PC) digital image processing systems (DIPS) or digital photogrammetric instruments (DPI) (OEEPE, 1996).

There are different kinds of topographical structures in the areas which were affected by the earthquake, and, for which the orthophoto maps will be produced; there is no homogenous, standard and specific topographical structure and plant coverage in these areas. Since the area affected by the earthquake is very wide, there have been considerable differences in different parts of this area in terms of topographical characteristics; even in one map or one model area.

In this study, by comparing the DEM data and contour lines produced by two different methods with each other in accordance with several criteria; the most appropriate methods have been researched in order to perform the production of DEM data and contour lines precisely and rapidly.

2 DEFINING OF THE PROJECT AREA

İzmit Earthquake occurred in the area has efffected the big cities such as Gölcük, Bursa, Adapazar , Kocaeli, İstanbul, Yalova, Eskişehir, Bolu and Bursa located in Marmara region. The production of approximately 1300 sheets of 1:5.000 scaled orthophoto maps has been completed in order to determine the damages of the earthquake and to use them in several planning activities. 1:16.000 scaled aerial photographs taken with Zeiss RMK-TOP 15 aerial camera (focal length :153 mm.) have been used in the production of the orthophoto maps mentioned above. The number, density and places of the geodetic ground control points in the whole project area have been planned according to the kinematic GPS-supported photo flight. The number of aerial photographs covered the whole project area, forward and side overlap rates, the number and contribution of the ground control points, the number of stereo pairs the number of the photogrammetric blocks formed in the project area, the accuracy results obtained from the aerial triangulation measurements and the photogrammetric block adjustments, the technical specifications of the hardware and software used in the project; in shortly, all applications related to aerial triangulation performed in the project area have been explained on the Paper-1127 in detail.

Additionally, the production of the orthophotos and photo-mosaics from the DEM data; the production of orthophoto maps which contained the map sheet border lines, grid lines, contour lines, height points, map sheet information, some explanations and texts by using photo-mosaics produced in advance; the technical specifications of the hardware and software used in the project; in shortly, all applications related to the production of the orthophoto maps and photo-mosaics in the project area, have been explained on the Paper-1127 in detail.

3. PROCESSİNG OF DEM DATA AND THE EXPERIMENTS

The research activities performed for the determination of the most appropriate methods in order to produce DEM data and contour lines required for the production of the orthophoto maps have been explained on the Part-4 in detail. The processing steps applied and the hardware and software used in the applications are stated below.

3.1 Scanning of the Aerial Photographs

The 1:16 000 scaled, black and white (b/w) aerial photographs taken according to the kinematic GPS-supported flight planning with the Zeiss-RMK TOP 15 aerial camera having 153 mm focal length, % 60 forward overlap, % 30 side overlap, 23cm x 23cm formatted were scanned in 21 micron by using Zeiss-PHODIS SCAI high precision scanner.

3.2 The Photogrammetric Aerotriangulation Processes

By using the scanned aerial photographs existing in the photogrammetric blocks formed by taking care of the density of the selected ground control points; the image coordinates of the control, pass, parallax and photogrammetric tie points were measured in the Zeiss-ST 10 digital photogrammetric instrument; the ground coordinates of the projection centres of the photographs existing in the block were calculated by processing the kinematic GPS data with SKIP software; then, the block adjustment with PATB-GPS software was performed by using the measured image coordinates of all points, the coordinates of the geodetic control points and the results of SKIP process. An appropriate and regular photogrammetric block was

formed and finally, a file which contained the exterior orientation parameters of all aerial photographs existing in the block was obtained as a result of these processes.

3.3 Forming the Stereo Models in the Block

The project files were created in Vision-SOFTPLOTTER digital instruments; required parameters related to the production of the block, stereo model, orthophoto, DEM, TIN, mosaic and digital vector map compilation were introduced in the systems; the interior orientations of all scanned aerial photographs in the block were performed full-automatically by using the camera parameters used in the project; the block triangulation was calculated with the use of the block triangulation parameter file; finally, all stereo models in the block were formed.

3.4 Creating the Digital Vector Data Files

The contour lines and height points were digitised in the stereo models created in the digital photogrammetric instruments, and they were registered to the data files. This vector data produced in Vision-KDMS format was converted to MicroStation-DGN format; they were edited and corrected in the PC-based work/stations and checked the edges of the maps in the systems. Finally, the corrected contour lines and height points in MicroStation-DGN format were converted to Vision-KDMS format in order to control the corrections and editing in the stereo models.

3.5 Checking the Edited Contour Lines in the Stereo Models

The 3D-contour lines and height points converted to KDMS format were controlled again in the stereo models in the digital instruments and, the compatibility with the ground surface was provided by doing some small corrections.

3.6 The Production of TIN and DEM Data

TIN data in the triangulated form was calculated by using the contour lines in the digital instruments; additional DEM points were measured along the break lines, in the characteristic points and necessary areas. At the end of this step, the production of the digital contour lines and DEM data necessary for the production of the orthophoto maps were made available.

4 THE PRODUCTION METHODS OF THE DEM DATA AND CONTOUR LINES

In the study, three different approaches for the production of DEM data were investigated.

4.1 The Production of the DEM Data Manually, Semi-Automatically and Full-Automatically

In this method, DEM data have been produced full-automatically by using the stereo models formed in the Vision-SOFTPLOTTER digital photogrammetric instruments. By checking the accuracy of DEM data in the stereo models produced full-automatically in the digital instruments, existing errors in DEM data were searched. It was observed that, the DEM data produced by the automatic methods yielded satisfactory and good results in the areas were significant height differences (roughy areas) and plants exist; too many errors in DEM data

were available especially in the forestry, urban areas, too low and high contrasting areas, flat, sandy and swamp areas; and, the amount of the errors in the DEM data exceeded the acceptable error limits, so, the data needed to be edited. The final orthophoto maps and contour lines to be produced from this data were also erronous. It was determined that many editing works were also needed in the roughy areas which the automatic DEM production gave good results. The DEM in regular grid structure and, TIN data in triangulated and irregular point structure collected in 20m x 20m density have been automatically calculated approximately in one hour by using one stereo model formed from the scanned aerial photographs in 21 micron. Followingly, in order to provide the exact compatibility with the ground surface of DEM data, the erronous points have been edited and corrected. The contour lines were generated in 5 meters from the DEM points compatible with the ground surface. Although error-free DEM data having enough density and have been used for the production of contour lines, it was determined in the controls that the contour lines generated from DEM data were not compatible with the ground surface; the contours especially in the hilly and mountainous areas, rivers and streams, ridge lines showed bad results. In order to solve the problems mentioned above, the break-lines were defined by measuring additional DEM points in the streams, rivers and ridge lines in the stereo models which contained the DEM or TIN data; additional height points were measured in the characteristic points such as hills, tumulus, cavities, defiles and cocurdans; closed areas such as wide rivers, sees, lakes, ponds and rice fields were defined as cut-out areas in the stereo models. According to the final results obtained from the collection and editing of DEM or TIN data performed manually in about 10 stereo models, it has been seen that the DEM or TIN points of one stereo model (about one 1:5.000 map sheet) could have been edited and corrected in 8 hours and, the contour lines having minimum errors have been produced at the end of all processes. Against these corrections of the DEM points, it was determined that the contour lines were not still compatible with the ground surface; the production of DEM data, which was the most important step of the orthophoto map production, took very much time. According to these results, the production of the orthophoto maps will not be able to be carried out on time and the project will not be completed in specified time. By considering the results obtained from the experiences performed in nearly 10 stereo models which had different topographical characteristics, it has been decided that it was compulsory to try the another method related to the DEM production. It was understood that these kinds of errors may be existed very much in the areas which had the different topographical characteristics, editing and correcting of this data may take much time; the automatic DEM collection and the production of the contour lines of each stereo model from DEM data will may be completed approximately in 2 days in the earthquake region which especially has the forestry and urban areas; for that reason, it was understood that it was almost impossible to use the first method in the production of DEM.

4.2 The Digitisation of the Contour Lines Directly from the Stereo Models and the Production of DEM Data from These Contours

At the end of getting non-satisfactory results from the method pointed out in Part 4.1, it has been decided that it could be useful to apply the second method and, some experiences were performed in the same 10 stereo models. For this purpose, the contour lines have been digitised in point-to-point mode in the stereo models formed with the scanned aerial photographs in the digital instruments; additional DEM points have been measured in the characteristic points such as hills, tumulus, cavities, defiles and cocurdans and along the break-lines such as streams, rivers and ridges. At this phase, it has been pointed out the DEM data required for the orthophoto production may be produced with two different methods by using the contour lines (Index, intermediate and supplementary contours) produced from the

digitisation points with enough density and exactly compatible with the ground surface; and it has been decided to study two different methods.

In the first approach; TIN triangulated data was calculated in the digital instruments by using the contour lines and height points; DEM data was obtained from TIN data in 20m x 20m density within regular grid structure. In the controls performed in the stereo models, the compatibility with the ground surface of DEM data were checked. It could be seen that this data was not compatible with the ground surface; the erronous DEM points were edited and corrected. It was also understood that the measurement of the additional DEM points were required in the characteristic points and lines as in specified Part 4.1. The 1:5.000 scaled orthophotos and photo-mosaics were produced with the appropriate and correct DEM data obtained by all processes and measurements. And then, 1:5.000 scaled orthophoto maps were produced with the appropriate and correct contour lines. But, it was understood that, this method could take so much time; the digitisation of the contour lines of one stereo model lasted 1 day; the production of DEM of the same stereo model lasted 1 day; finally, the necessary data for the orthophoto map production may be produced in 2 days.

In the second approach; TIN data was directly calculated by the triangulation technique in the digital instrument by using the contour lines captured manually in advance; additional DEM points were manually measured only along the break-lines such as streams, rivers, ridges, upper and lower borders of cavity in the stereo models which contained TIN data; so, the orthophoto images and orthophoto maps were produced by using the final DEM and contour lines. It could be seen that the planimetric and height accuracies of the final orthophoto maps were nearly the same as in the previous approach which was expected very correctly. Finally, it was decided that, DEM data may be produced in a very short time by collecting in TIN structure from the contour lines digitised manually. In the production of the orthophoto images, contour lines and orthophoto maps related to the Marmara Earthquake area, the last approach was used.

5 CONCLUSION

It is possible to produce the DEM or TIN data with three different methods explained in Part 4.1 and 4.2. The DEM data produced with three different ways normally provides all positive conditions for the production of the 1:5.000 scaled orthophoto maps. But, when some factors such as time, cost, economy and production speed are taken into consideration, the most appropriate and correct results may be able to be obtained by applying the second approach were is explained and applied in Part 4.2.

REFERENCES

Ackermann, F., 1991, Structural Changes in Photogrammetry, 43. Photogrammetric Week, 9-14 September 1991, Stuttgart University, Germany, Heft 15: 9-24.

Ackermann, F., 1995, Automation in Digital Photogrammetry by Digital Image Processing, Türk Haritac l ğ n n Yüzüncü Y l -TUJJB ve TUFUAB Kongreleri Bildiri Kitab , 1-5 May s 1995, Ankara, Cilt 4 :1171-1180.

Chilchi, M., 1997, Production of a DEM Using Space Data, Space Cartography' 97, GDTA, 01/09 to 17/10/1997, Toulouse, Cedex, France.

Fritsch, D., Haala, N., Hahn, M. and Sester, M., 1997, Digital Photogrammetry in Small Scale Imagery, Camera Models and Sensor Systems, Fundamentals of Digital Image Processing, Segmentation and Classification, Matching Techniques, Digital Orthophoto, Photogrammetric Orientation Tasks, Surface Reconstruction-Digital Elevation Models, Extraction of Cartographic Features, Institute of Photogrammetry, University of Stuttgart, Germany.

Krzystek, P., 1991, Fully Automatic Measurement of Digital Elevation Models with MATCH-T, 43. Photogrammetric Week, 9-14 September 1991, Stuttgart University, Germany, Heft 15:203-204.

Kraus, K., 1993, Photogrammetry-Volume 1, Fundamentals and Standard Processes, Fourth Edition, Ferd. Dümmler. Verlas, Bonn, Germany.

OEEPE, 1991, Test on Orthophoto and Stereo-Orthophoto Accuracy, European Organisation for Experimental Photogrammetric Research, OEEPE-Official Publication No:25, May 1991, Enschede, Netherlands.

OEEPE, 1996, OEEPE-Workshop on Application of Digital Photogrammetric Workstations, European Organisation for Experimental Photogrammetric Research, OEEPE-Official Publication No:33, June 1996, Enschede, Netherlands.