MAPPING OF WIDE AREAS USING DIGITAL PHOTOGRAMMETRY: A CASE STUDY IN TURKEY

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ABSTRACT

In recent years, the number of digital photogrammetry applications has been increased with high acceleration by means of partially automated data processing and the developments on computer technologies (powerful memories, rapid operators etc.). Topographical mapping is one the most common application fields with the advantage of quite quick data acquisition from wide areas. In this respect, a two-stage Project (called as M3 and M4) was planned in 3750km^2 Bursa metropolitan area, Turkey and the first stage M3 was realized during three years in between 2008 and 2011. In M3, 1/1000 scaled aerial photos were obtained using advanced Vexcel UltraCam-Xp digital camera and 1/1000 scaled approximately 4500 vector maps , 4500 orthophotos and 1/5000 scaled 300 vector maps were produced by photogrammetric assessment. This paper aims to describe the processing steps of M3 including field survey for geodesic infrastructure, flight plan and calendar preparation, achievement of aerial photos, photogrammetric assessment and map production, control processes at the terrain and office, encountered problems and the solution advisories to set light to similar applications.

1- INTRODUCTION

Digital photogrammetry that is accepted as a revolution for photogrammetry is a technique of acquiring high-precision measurements from digital aerial photos. The main advantage of this technique in comparison with analytical and analog methods is the usage of digital imagery. Additionally, whole photogrammetric assessment process is digital my means of automated components. By the help of this technique, digital map production from aerial photos became attractive on the areas with local up to regional coverage. However, computer-based evaluation systems are rather sophisticated and amount of data is usually huge. Accordingly, they need advanced and expensive systems (Höhle, 1996).

Inspiring the advantages of digital photogrammetry, a two-stage Project (M3-M4) was improved in Bursa Metropolitan area (BMA), Turkey. The first stage M3 was performed successfully between 2008 and 2011 and M4 will be finished in 2013. M3 covers the first requested area by Bursa Water and Sewage Management Head Office (BUSKİ) (the employer) and M4 is the second area that can be thought as the expansion area of M3.

The main objectives of this Project can be summarized as the acquisition of digital aerial photos and production of 1/1000 and 1/5000 scaled digital vector maps, orthophotos and three dimensional digital terrain models (DTM) by photogrammetric assessment.

Towards these purposes, the paper is organized as follows; Section 2 explains the general properties of Project area. Section 3 informs about the establishment of ground control points (GCPs). Section 4 describes the methodology for digital map production including acquisition levels of digital aerial photos, the photogrammetric assessment and map production and summarized control activities. Finally, section 5 concludes the paper.

2- PROJECT AREA

Bursa Metropolitan Area (BMA) is located in Marmara region on the North-West part of Turkey. The city has various topographic formations and the altitude changes from 100m to 2500m. The population is around four million and annually increases with 5%. Figure 1 shows the Project area (white border).

Figure 1. Project area (white)

3- ESTABLISHMENT OF GROUND CONTROL POINTS

Before photogrammetric flight, a GCP network was established including 24 first level, 43 second level and 1215 third level condensation points referring 10 Turkish National Basic GNSS Network (TUTGA) points. First, second, and third level condensation points are called as ‘C1’, ‘C2’, and ‘C3’ respectively. C1 and C2 GCPs are arranged with 15-20km and 5-15km horizontal distances. C3 GCPs are in between 0.8-1,5km. Figure 2 depicts C1, C2 (a) and C3 (b) GCP construction types.

(a) **(b)**

Figure 2. C1, C2 (a) and C3 (b) GCP construction types

In the Project, the coordinates of GCPs are determined by static GPS observations covering approximately 3500 km^2. Helmert orthometric heights of 459 GCPs were measured with ±1.5 mm/km accuracy depending on Turkish National Vertical Control Network (TUDKA) that was established between 1997 and 2001 in the ITRF datum by 700 geodetic points with 25-30 km horizontal interval.

On the GCP distribution, regular triangulation is very significant. First, we avoided using triangles that have acute angles on the network. Additionally, we did not exceed the tolerance limits of aforementioned distances considering the GCP types. Figure 3 and 4 show the distribution of C1, C2 and C3 GCPs respectively.

Figure 3. Distribution of C1 and C2 GCPs

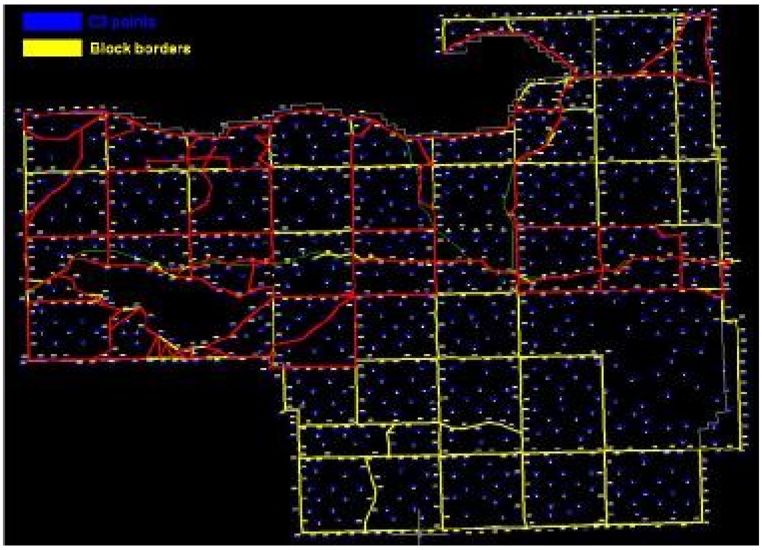

Figure 4. Distribution of C3 GCPs

4- DIGITAL MAP PRODUCTION METHODOLOGY

4.1 Acquirement of Aerial Photos

In M3, Project area was divided into two sub-areas considering the requirements of BUSKİ and aerial photos were acquired by two different photogrammetric flights that have a year time interval. Figure 5 represents flight plan and including blocks.

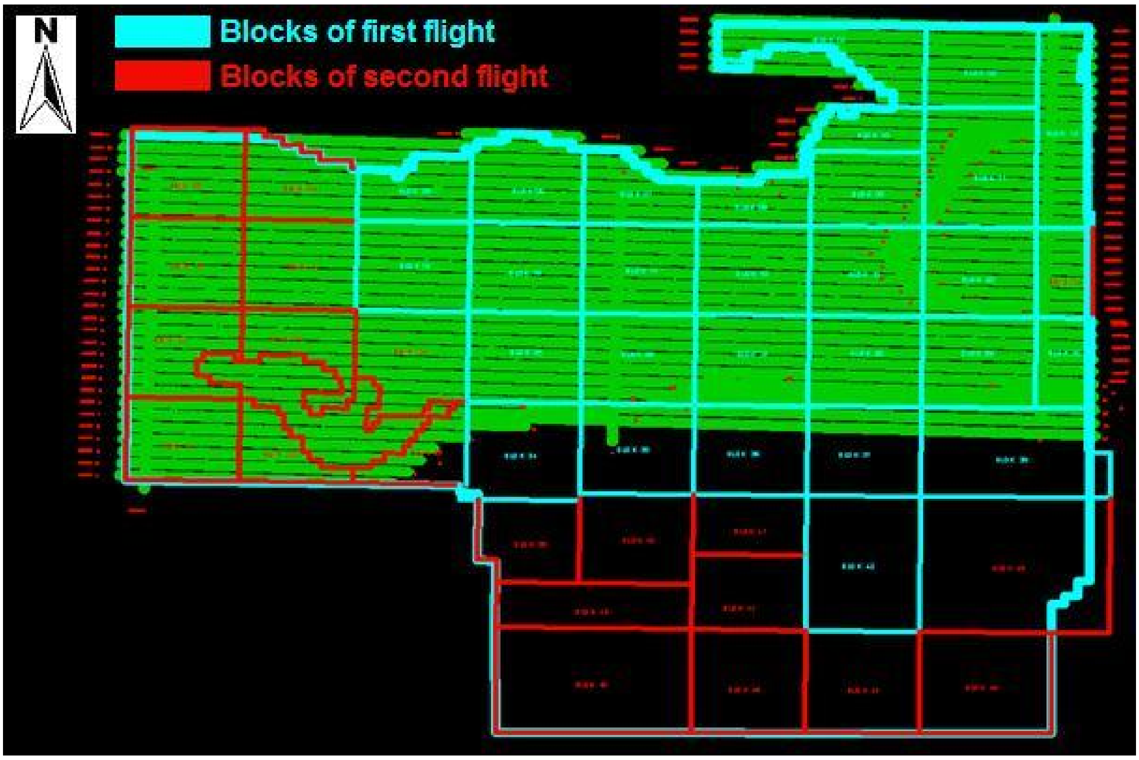

Figure 5. Flight plan

The first flight was realized July 2009 and 60% of Project area was covered The aerial photos were acquired between 09.30-16.30 hours. At this flight, entire Project area could not be imaged because the elevation of mountanious parts reach up to 2300m with snow and haze and the altitude of aircrat was limited with 1733m. The imaging of mountanious areas and an additional area that can be seen on the left side of Figure 5 were performed on July 2010 with second flight.

According to Shortis and Beyer (1996), digital camera can be categorized as digital still camera and analogue video camera. Digital camera could be used to acquire single photo at a particular instance and the photo could be stored in the camera on-board (Ahmad, 2006). On the flights, considering technical conditions 'Vexcel UltraCam Xp' and 'X' digital cameras were used respectively that were integrated to the body of Cessna 402. Using digital camera, the difficulties of usage 70 film roll for 15000 photographs, photographic processing, materials and the requirements of manpower, stuff and hardware, and the storage and archiving are eliminated. Figure 6 shows the basic equipment used for flights.

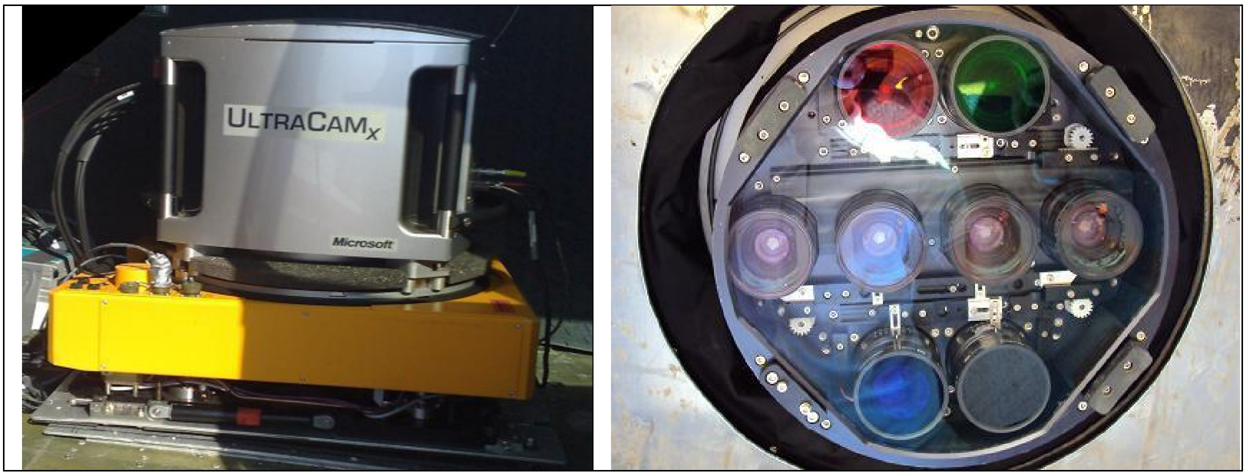

Figure 6. Basic equipments of flights

By the usage of digital camera the image quality was improved supporting the increase of speed and accuracy of photogrammetric triangulation and processing. And finally more qualitative orthophoto and vector maps have been generated.

The information about the first flight and imaging is given at the Table 1.

Table 1. Flight and imaging information

Parameter	**Value**
Camera focal length (f) :	100.5 mm
Image size	11310 pixel x 17310 pixel
Pixel size (Ps)	6 µm
Distance between columns	1100 m
Base	340 m
Flight height (h)	~ 57000 ft = 1733 m
Photo-scale	~ (100.5/1733000) = 1/17300
GSD	$(Ps / f)\ .\ h\ .$ 0.1034 m
Direct sensor orientation	GPS/IMU
Frontlap and slidelap of aerial photos	70% - 30%

After achieving raw photos, their level were increased from ‘L0’ to ‘L3’ by a group of processing steps to use in photogrammetric assessment softwares. The meanings of processing levels are as following;

- Level-0 Verified data, same as Level-00, but no duplicate copy exists.
- Level-1 Internal intermediate format, maintained as 13 sub-images, but radiometrically corrected using calibration files.
- Level-2 Deliverable format, the panchromatic sub-images are stitched and geometrically corrected using the calibration files. The four color channels are in one file, separate from the panchromatic data.
- Level-3 Pan-sharpened color images in R-G-B, in CIR or in R-G-B-NIR. Format in 8 or 16 bits, at the discretion of the user. TIFF or JPEG standard format.

A sample processed aerial photo that was obtained by Project can be seen in Figure 7.

Figure 7. An obtained aerial photo in Project

4.2- Photogrammetric Assessment and Map Production

As usual, the photogrammetric assessment was realized using stereoscopy. Stereo models were generated using stereo photos derived from flight columns and manual vectorization was performed by the operators. Entire ground objects which cover an area bigger than $5m^2$ were included to generated classes such as building, road, pavement, street drain, single tree, fruit bowl, olive grove, telephone pole, electric pole etc. Also the elevation of requested ground objects (buildings etc.) and terrain were marked and contour lines were generated in 1m height interval.

Using vectorized ground objects, marked height values and contour lines, 1/1000 scaled first level map sections were generated. Then, these map sections were completed on the terrain adding unnoticed details on the vectorization. As usual, the most significant problem on the photogrammetry technique is indiscriminable short objects on the aerial photos because of tall object's coverage such as trees. By completing first level map sections with the information derived from terrain, second level map sections were obtained.

After creation of second level map sections, control mechanism steps in. That means, before the generation of final third level map sections, whole errors and lacks on the production have to be fixed and corrected. In the Project, control activities have been implemented by Bulent Ecevit University (BEU) that is located in Zonguldak City, Turkey considering five main steps. These steps are as following;

- Cartographic controls
- Stereo-model controls
- Completion control of ground objects on the terrain
- Geometric location accuracy control on the terrain
- Orthophoto controls

According to these controls, errors and lacks of second level map sections were decreased to minimum and third level map sections were produced which are the final vector map products.

By photogrammetry, digital terrain models (DTMs) that are the 3D cartographic representation of bare ground of interest area can be generated. In fact, the first 3D product of photogrammetry is a digital surface model (DSM) which determines a surface including the top of entire ground objects such as buildings, forest, vegetation etc. By filtering these objects DTM is obtained. In this Project, DTM was generated with 5m grid spacing using whole elevation values from bare ground, contour lines, break lines, mass points etc. These elevation values were spread to the entire Project area by bilinear interpolation method.

Many users continue to rely on orthophotos for the detail needed, for example, in urban and cadastral work, and will continue using it to complement the digital information (Neto, 2002). From this point of view, at the last step, using aerial photos and the DTM, orthophotos were created. Figure 8 shows an example of orthophoto and a vector map for same area.

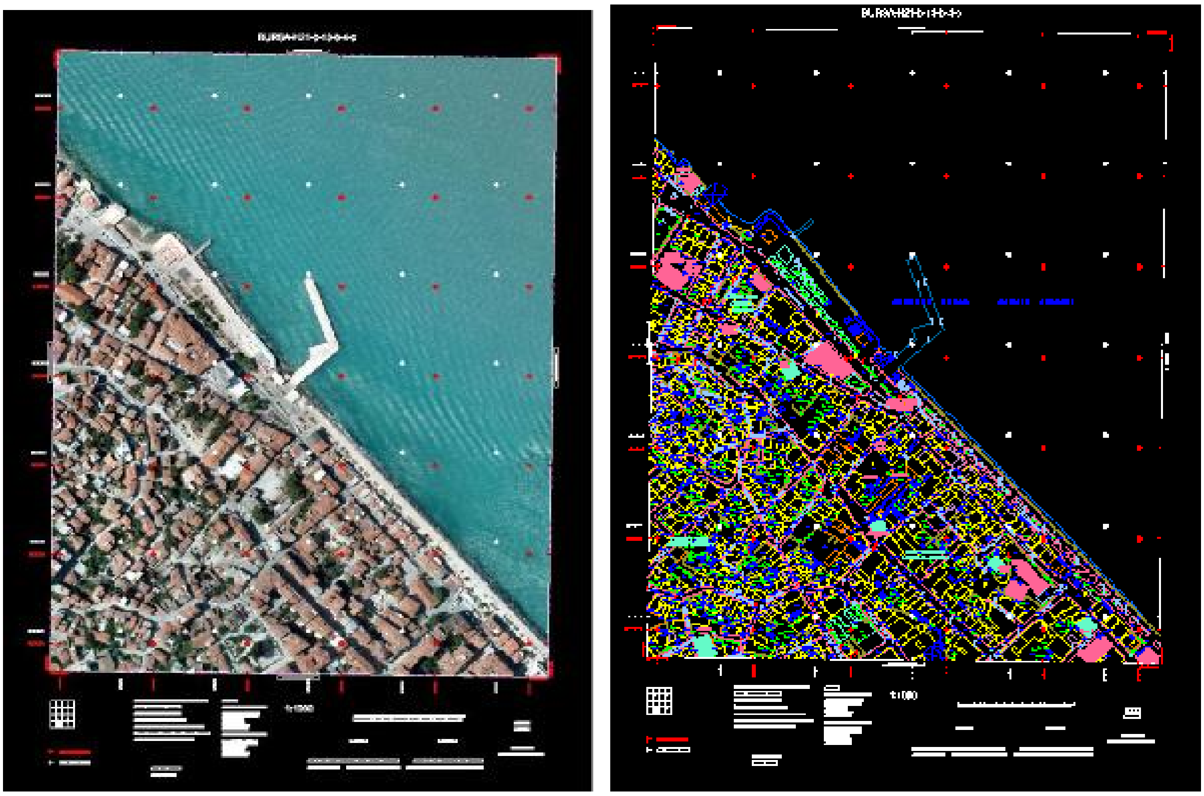

Figure 8. An example of orthophoto and vector map for same area

By means of the Project, 1/1000 scaled 4500 vector maps and orthophotos were obtained. Additionally, approximately 300 1/5000 scaled vector maps were generated by generalization of 1/1000 scaled vector maps.

5- CONCLUSION

The summarized Project is the fist leading project where the 1/1000 vectoral and orthophoto maps are produced in the national standards using fully equipped advanced digital aerial cameras and softwares. So it is monitored countrywide owing to provide information and first experiences.

Digital Photogrammetry has lots of advantages in comparison with analog and analytical photogrammetry techniques.

The most important problem for photogrammetric assessment is the tall objects such as trees that covers the short objects. This problem can be soved by completion processes on the terrain.

Control activities are crucial on decreasing errors and lacks to minimum and produce the best map products.

It is well known that professional technical staff in the governmental agencies is absent for the effective application and checking of the great projects which uses high technologies in Turkey. Therefore, receiving advisory from a university (such as BEU) having enough staff is a conformable decision. It is an important situation to provide development of University- Industry cooperation countrywide.

The acquired data from digital photogrammetry is an important source for the monitoring of geodynamics of the project area. The academical staff of BEU Geodesy and Photogrammerty Engineering Department plan to use Project data as a source for master/doctorate studies and the scientific applications.

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