

# GPS VIRTUAL STATION TECHNIQUE (GPSSIT) AND ITS CHALLENGE IN TERRESTRIAL PHOTOGRAMMETRIC APPLICATIONS

O. Corumluolu<sup>a</sup>, I. Kalayci<sup>a</sup>, S. Durduran<sup>a</sup>, C. Altuntas<sup>b</sup>, I. Asri<sup>c</sup>, A. Onal<sup>c</sup>

<sup>a</sup> Selcuk University, Engineering and Architecture Faculty, Geodesy and Photogrammetry Department, 42075 Konya, TURKEY –

<sup>b</sup> Selcuk University, Sarayonu Higher Vocational School, Surveying Division, 42075 Konya, TURKEY –

<sup>c</sup> Selcuk University, Institute of Natural Sciences, 42075 Konya, TURKEY –

(ocorumlu, ikalayci, sdurduran, caltuntas)@selcuk.edu.tr

## Commission III, WG V/4

**KEY WORDS:** Textured image, Digital Photogrammetry, 3D model, GPS Virtual Station, GPSSIT

### ABSTRACT:

GPS Virtual Station technique fundamentally depends on determination of a virtual point by GPS that is just about 1,5 meters above the ground or a platform surface and then to the use of it by other surveying and/or photogrammetric instruments such as a total station and/or a camera. Thus, the technique offers a challenge in terrestrial photogrammetry to determine the coordinates of control points distributed on each facade of any object in any size and in a reference system, which is globally available, and without using a network of points set up on the ground and surrounding the object. The technique is also capable of determination of camera perspective centre's coordinates by the use of GPS Virtual Station which is determined by the GPS antenna. In this process, first, GPS antenna is set up on a tripod with a leveled tribrach to collect GPS Virtual Station coordinates and then it is removed from the tribrach and replaced with a camera (i.e. digital camera) in a similar way of that can even be followed with total station to be used for the measurement of control points on the facades. So, it means that the network of points to be set up for the measurements of control points on the objects in interest and which is the most cost effective part of a over all project is removed, no more hustle for it, and three unknown parameters are now known values when considering that the camera perspective centre is determined as GPS Virtual Station, and so that the number of control points on the facades can be reduced, and there is no location limitation for chose of points, so that they can freely be chosen at any time (even in the middle of a measurement section if some kinds of problems are met, such as GPS signal blockage and object coverage problems) at any where around the object and finally, every object measured using this technique in any part of the world can easily and spatially linked and referred to one another with respect to the same reference system.

In this study, the technique mentioned above was utilised to create a final product as an originally textured virtual reality 3D photogrammetric model of a historical site, which is a unique sample of a cultural asset remained from its own time. It is Aladdin Mosque built up at the top of the Aladdin Hill where takes place at the centre of Konya. 3D model of the site is also ready to be put into the internet and onto a CD to distribute and interact in a GIS environment. As a final outcome of this study, it can be stated that the technique proposed here represents an encouraging performance in the point of accuracy, and project speed and economy as well.

## 1. INTRODUCTION

Soft copy photogrammetry is one of the most rapidly developed, cheapest and easiest phenomenons which have been never experienced in surveying discipline over resent years. It is the result of digital technology adapted to photogrammetry. Digital technology offered great opportunities for photogrammetrists to replace their old techniques and huge and heavy devices such as optic-mechanic even analytical streoplotters in different sizes. It was a revolutionary achievement that photogrammetrists ever met before (Fraser & Edmundson, 2000). After couple of years, a second achievement came true: that was the emerge of digital cameras. At the beginning, they were useless for professionals with 2 – 3 Mega Pixels. But now, they offer more than 5 – 8 Mega pixels. These precisions are quite encouraging especially for terrestrial uses in photogrammetry. Meanwhile, most special challenge which is most important than that occurred in photogrammetry was achieved in the general frame of spatial data collection content at the beginning of 80's. It was the civil use of satellite systems for the spatial data

collection processes: So it is the use of GPS. These two challenges in spatial data collection processes pushed the societies to develop their information systems rapidly. The third one is also an opportunity to obtain digital images of several wavelengths from satellites. That is now well-known remote sensing. These last two spatial data collection techniques both can now be used for certain cases in photogrammetry. For example, GPS is used in aerial photogrammetry to observe perspective center coordinates of camera onboard a plane and to determine the coordinates of control points on the ground. Remote sensing images from satellites in space are also used in archeological and architectural photogrammetries.

These three new age technologies are now available to be used in terrestrial close range photogrammetry. Remote sensing images are able to be used to obtain textured 3D terrain models with 3D building models which rise up on these terrain models. They can also be used to determine environmental features such as roads that link other sites to the mission area and etc. 3D building models can also be created as models which are textured with original

sight of the buildings produced from digital images collected by digital cameras and by softcopy photogrammetry technique (Gruber et. al., 1995). Afterward, these models can be included in a GIS such as Historical Asset Information and Management System and then published on the internet to share with citizens and other professionals (Ioannidis et. al., 2002). It could also be included into a Virtual Tourist Information System that is even supported by a vehicle navigation and tracking system (Malaka & Zipf, 2000). In this case, GPS comes into use. Not only this case, but also there is another place to use GPS in terrestrial photogrammetry especially in architectural and archeological photogrammetric studies and works. This can be a similar way of use as being in GPS supported aerial photogrammetry. So, it is the determination of camera perspective center's coordinates. With only a difference, which is that the camera is not onboard a plane, just top of a digital camera few decimeters above from the land, on a tripod. This technique is also capable of providing fixed rotation angles of digital camera as well.

Using above techniques we can have a very attractive system which is viable and can support itself.

## 2. GPS SUPPORTED TERRESTRIAL PHOTOGRAMMETRY



Figure 1: Removing GPS antenna from the levelled tribrach

First of all, GPS can be used to determine the nation wide local coordinates of control points fixed on facades of any object that is subject to photogrammetric measurement. At the first look, it can be said how GPS can be used for this purpose. There is a technique which is called as GPSSIT (GPS Virtual Station Technique) and was suggested by some researchers from Turkey (for more details, refer to the Corumluoglu's paper (Corumluoglu et. al., 2003)). This technique uses GPS to determine the coordinates of reference center of any surveying devices without any extra hardware and costs nothing. Core of the technique depends on the use of a single tribrach for each device to be set up on a tripod. So what ever the device it is used, the technique needs only a small adaptor apparatus between triprach and the device to be used. For example, this technique was first used to determine the optical center of an EDM set up on a tripod. Therefore, it can also be used to determine the coordinates of a digital camera set up on a tripod as well.

In the form of GPSSIT that utilizes EDM, the technique uses the combination of EDM and GPS antenna by the help of a leveled single tribrach (figure 1). Thus, the coordinates of optical center of EDM are able to be determined easily in the way of similar strategy and

technique that have been being used successfully in GPS supported aerial photogrammetry, if it is recalled here (Ackermann, 1994, Corumluoglu, 1998). After the optical center coordinates of EDM are determined up in the air by GPS antenna using GPSSIT, coordinates of details and features on land and even the coordinates of the control points chosen on facades of an object, which is subject to photogrammetric processes, can be found out by referring the EDM measurements to the optical center of EDM defined by GPS. Here can generally be said, that GPSSIT can practically be used to determine the coordinates of control points chosen on the facades of any object in terrestrial photogrammetry. Each object to be evaluated photogrammetrically can then be described with respect to the others in a same reference coordinate system and land features and details surrounding the each object as well, even if these objects are far away kilometers from each other. Thus, it is being provided a unity of coordinate for all of the objects and control points in photogrammetric projects (figure 2). Even they can be produced in different times and easily be included in any previous photogrammetric project which was carried out by means of digital photogrammetry and GPSSIT.

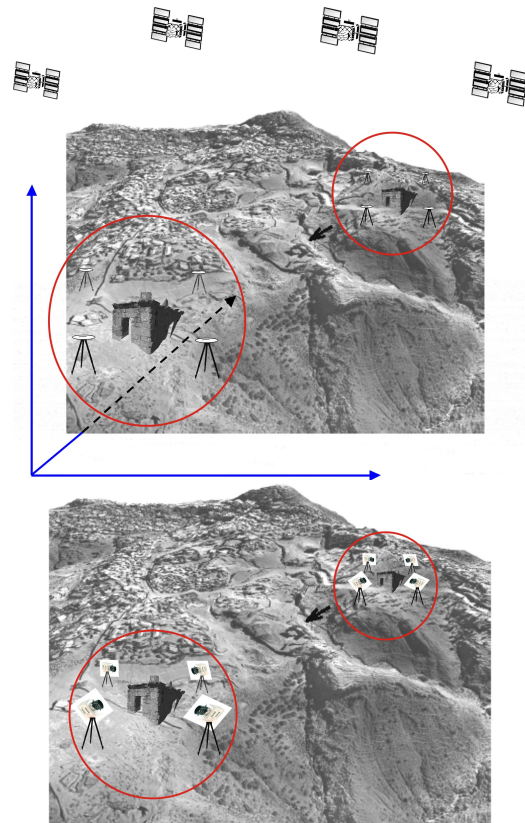


Figure 2: Different locations for GPS supported terrestrial photogrammetry by GPSSIT and a unique reference system.

There is one more thing that GPSSIT offers for terrestrial photogrammetry. It is the use of the point determined by GPS antenna on tribrach for a digital camera as well (figure 3). Thus, the camera perspective center is not any longer an unknown. Its coordinates are similarly determined by the GPS antenna as it is being in the case of EDM and especially in the case of GPS supported triangulation in aerial photogrammetry. This reduces the

number of parameters in photogrammetric adjustment and strengthens it.

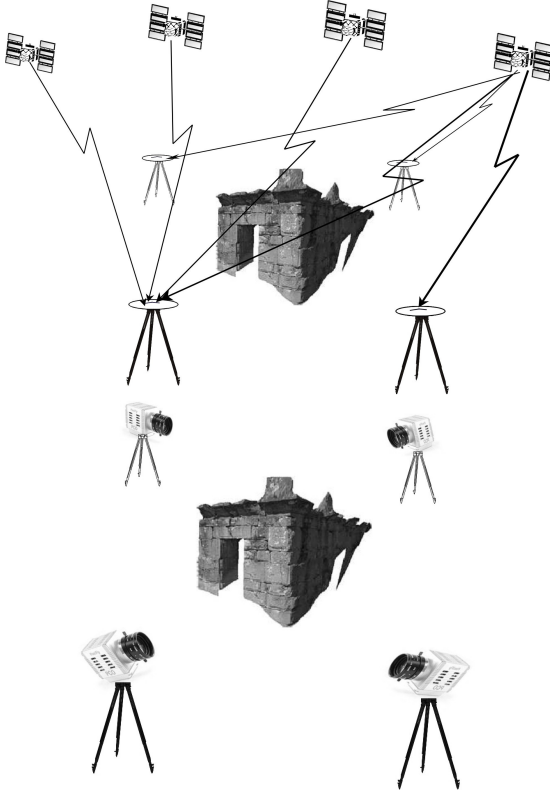


Figure 3: First and second steps of GPSSIT supported terrestrial photogrammetry

### 3. MATHEMATICAL MODEL

Bundle adjustment is the most appropriate adjustment method used in digital photogrammetry since it depends on analytical principals and is a numerical technique. Colinearity condition, which depends on a line aligning the points on object, perspective center of camera and on the image of the object, is the algorithm that forms the mathematical model of GPSSIT supported terrestrial photogrammetry. Respecting this condition, all the lines passing through a central point and touch to two parallel planes at the each ends of the line are divided in two parts by the camera perspective center and the rate of these two parts on the same line one to another will be the same and constant for the other lines as well. Point of photogrammetric view, the central point described here is the camera perspective center and the plane close to the point is called as image plane and it is a real plane. The important description here, which does not match the theory above, is that the other plane is not a plane in practice. It is often an actual 3D space. For a metrical evaluation, image and object mediums both must be referred to one apiece metric system. These two reference systems are called image and object reference systems in photogrammetry. In GPS supported terrestrial photogrammetry, image coordinate system is the same as image coordinate system in the current digital photogrammetry, in spite of that the object coordinate system is designated with respect to GPS coordinate system that uses WGS84 datum. The coordinates

obtained in GPS coordinate system can be transformed into a desired local coordinate system if it is required. This requirement comes out only if there is an offset between the point determined by GPS antenna and the point that the camera perspective center is referred. In the other case, the mathematical model to be formed photogrammetrically can be described directly in GPS coordinate system without the need for such a transformation. In this case and even considering that the coordinate systems are not parallel one another, the equation, which expresses the relationship between image coordinate system and GPS coordinate system that the object is described in, can be given as below;

$$\begin{bmatrix} X_{GPS-i} \\ Y_{GPS-i} \\ Z_{GPS-i} \end{bmatrix} = \lambda_{ij} R_j \begin{bmatrix} x_{ij} - x_0 \\ y_{ij} - y_0 \\ -f \end{bmatrix} + \begin{bmatrix} X_{GPS-j} \\ Y_{GPS-j} \\ Z_{GPS-j} \end{bmatrix} \quad (1)$$

where,

$[X_{GPS-i} \ Y_{GPS-i} \ Z_{GPS-i}]^T$  : is GPS coordinates of i'th object point,

$[X_{GPS-j} \ Y_{GPS-j} \ Z_{GPS-j}]^T$  : is GPS coordinates of perspective center of j'th image,

$x_{ij}$  and  $y_{ij}$  : is image coordinates of i'th object point in j'th image,

$x_0$  and  $y_0$  : is image coordinates of image center,

$\lambda_{ij}$  : is scale factor of i'th point in the j'th image,

$R_j$  : is rotation matrix of j'th image with respect to GPS coordinate system and

$f$  : is focal length of the camera used.

After moving the term of  $[X_{GPS-i} \ Y_{GPS-i} \ Z_{GPS-i}]^T$  in equation 1 to the left side of the equation and then multiplying the both sides of the arranged equation by

$\frac{1}{\lambda_{ij}} R_j^T$ , the new form of the equation can be written as

below when it is divided the first and second rows of the equation by the third one.

$$x_{ij} = f \frac{r_{11-j}(X_{GPS-i} - X_{GPS-j}) + r_{12-j}(Y_{GPS-i} - Y_{GPS-j}) + r_{13-j}(Z_{GPS-i} - Z_{GPS-j})}{r_{31-j}(X_{GPS-i} - X_{GPS-j}) + r_{32-j}(Y_{GPS-i} - Y_{GPS-j}) + r_{33-j}(Z_{GPS-i} - Z_{GPS-j})} - x_0 \quad (2)$$

$$y_{ij} = f \frac{r_{21-j}(X_{GPS-i} - X_{GPS-j}) + r_{22-j}(Y_{GPS-i} - Y_{GPS-j}) + r_{23-j}(Z_{GPS-i} - Z_{GPS-j})}{r_{31-j}(X_{GPS-i} - X_{GPS-j}) + r_{32-j}(Y_{GPS-i} - Y_{GPS-j}) + r_{33-j}(Z_{GPS-i} - Z_{GPS-j})} - y_0 \quad (3)$$

$r_{11-j}, r_{12-j}, \dots, r_{33-j}$  are elements rotation matrix of  $R_j^T$

between image coordinate system and WGS84 coordinate systems. Here it is worth to mention that the coordinates of camera perspective center ( $X_{GPS-j}, Y_{GPS-j}, Z_{GPS-j}$ ) in the above equation are not any longer unknown and they enter to the equation above as constant values. Since they are determined by GPS antenna when GPSSIT supported terrestrial photogrammetry is used in the field. In this case, 7 unknown parameters in normal case reduce to 4, if the used camera is a camera whose image coordinates of its image center and its focal length ( $x_0, y_0, f$ ) are known. If the used camera is not a metric camera and image coordinates of its image center and its focal length ( $x_0, y_0,$

f) are not known, with such a camera, the number of unknowns for each image taken remains the same as four. But, total number of unknowns including those from all images increases only by 3 (they are internal parameters of the used camera) and becomes  $4n+3$  ( $n$  is number of images taken) in the adjustment.

#### 4. THE APPLICATION

To apply the technique, which is described here as GPSSIT supported terrestrial photogrammetry, into the practice, Alaattin Mosque was chosen as a pilot study area which is close to our university and in the town center of Konya. Alaattin Mosque is one of the important historical assets in Konya. It remained from era of the Seljuk and carries motifs that period of the time of Seljuk. Therefore it is a chronologically important work from that age.

In this study, several images covering all facades of the mosque were taken at several camera points surrounding the object. All images were taken by Sony-Zeiss 8 MP 0.7-2.8 with 4x zoom digital camera. GPS receivers used for GPS observation were two GPS receivers of Leica RS9500 series in our surveying lab.

First of all, several images covering all facades of the mosque were taken for planning purposes by the digital camera described above. Control points on the facades were then marked on these images. To make it simple, measurements of control points and determination of camera perspective center by GPSSIT were carried out in different time sections. First, control points marked on the previously taken images were measured and calculated their coordinates in WGS84 and then planning process for the camera points to be used for digital photography, photogrammetric evaluation and production of 3D model of the mosque were completed on those previously taken photographs taking into consideration those GPSSIT observations used for the determination of coordinates of camera perspective centers as well. After this photography by GPSSIT planning stage, all the images were taken as planned except a few that the site conditions did not allow. Then all the digital photos were evaluated in the terrestrial software of PhotoModeller that uses softcopy photogrammetry techniques and 3D model of the mosque were also produces (figure 4).

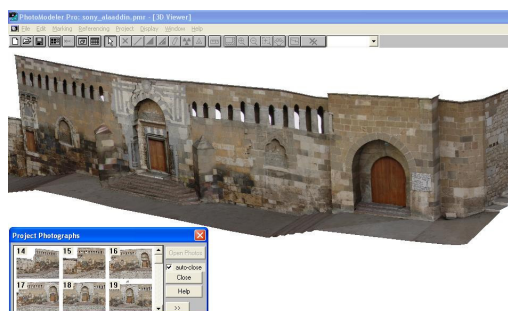


Figure 4: Front facade of 3D model of Alaattin Mosque.

#### 5. CONCLUSION

In this study, a GPS supported terrestrial photogrammetry technique was introduced that uses a GPS technique

called as GPSSIT. GPSSIT was successfully used to measure the control points chosen on the facades of an object that was subject to the digital terrestrial photogrammetric evaluation. It was also used to determine the camera perspective center coordinates as well. The outcomes from the study show that GPSSIT is capable of both producing camera perspective center coordinates and determination of control point's coordinates on object's facades. Thus, it suggests that the number of parameters in bundle adjustment can be reduced to 4 for each image to be evaluated in the close range photogrammetric software. If the non-metric cameras are used, the total number of parameters does only increase by 3 for internal parameters of the used non-metric camera than those being entered into the software when the metric camera is used.

#### 6. REFERENCES

- Ackermann, F., 1994, Practical experience with GPS supported aerial triangulation, *Photogrammetric Record*, Vol. 14(84), pp 861-874
- Corumluoglu, O., 1998, *GPS Aerotriangulation In Observation Space*, Ph. D. Thesis, University of Newcastle Upon Tyne, England, 233 pp.
- Corumluoglu, O., Ceylan, A., Kalayci, İ., 2003, The Use of GPS Free Station Technique (GPSSIT) for Detail Measurements, *Journal of Surveying and Cadastre Engineer, Turkey* sayı 88.
- Fraser, C.S. & Edmundson, K.L., 2000. Design and Implementation of a Computational Processing System for Off-Line Digital Close-Range Photogrammetry. *ISPRS Int. Journal of Photogrammetry & Remote Sensing*, 55(2): 94-104.
- Gruber, M., M. Pasko and F. Leberl, 1995, Geometric versus texture detail in 3D models of real world buildings, *Automatic extraction of Man-made objects from aerial and space images*, Birkhauser Verlag, Basel, pp. 189-198
- Ibrahim, A. M., 1995, Reliability analysis of combined GPS-aerial triangulation system, PhD Thesis, University of Newcastle Upon Tyne, UK
- Ioannidis, C., Potsiou, C., Soile, S., 2002, An integrated spatial information system for the development of the archaeological site of Mycenae , *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXIV-5/W10.
- Malaka, R. & Zipf, A. (2000), DEEP MAP - Challenging IT research in the framework of a tourist information system. *Proceedings of ENTER 2000*, pp. 15-27