GIS TECHNOLOGY AND TERRAIN ORTHOPHOTOMAP MAKING FOR MILITARY APPLICATION

Elshan HASHIMOV*
A.A. BAYRAMOV*
B.M. CHALILOV**

*Professor, PhD, Military Academy of Armed Forces, Ministry of Defense, Baku, Azerbaijan
**Photogrammetry engineer, "Rubikon Geosystems" LLC, Baku, Azerbaijan

In this paper, it is shown that GIS and photogrammetry technologiyes, determination of searching target coordinates for the operational desicion making are very important for the military application, for the combat control. With aim of orthophotomap making of the terrain and identification of terrain supervision there has been constructed 3D model for choosen mountainous terrain of Azerbaijan Republic using GIS technology. Based on this model there has been obtained a terrain profile and carried out mapping. Using ArcGis software there has been investigated possibility remain control on obserbvable and unobservable parties of terrain on supervision line from supervision point to target point.

Key words: *GİS, photogrammetry, orthophotomap, terrasın, unobservable object, geospatial technology.*

1. INTRODUCTION

Detailed information about territory, maps and other terrestrial pictures, calculation of coordinates are very important for organization and planning of military operations and combat control. Therefore, always geospatial information is necessary for solution of the military problems [1,2].

There could be such a critical situation during military operations that it might not be possible to observe terrestial targets, particularly targets of enemy located on mountainous terrain. In this type of case, there is indefinity in information thus the risk of wrong to decisioin-making process on destroying of the targets rises. Application of Geography Information System (GIS) technology is an optimal way to solve issue on 3D coordinate of hostile target and to define the distance [1,3].

There is an military application of geospatial technology, mapping and geographic information system (GIS) in Azerbaijan. Geospatial technology involve geodesy, mapping, photogrammetry, GIS and Earth aerospace remote sensing (EARS) technologies. In this paper we consider an especial branch of geospatial technology, that is a photogrammetry technology and military application for combat control. 3D model for choosen mountainous terrain of Azerbaijan Republic is constructed with aim of localization of unobservable objects using GIS technology. Based on this model there has been obtained a terrain profile and carried out mapping. Using ArcGis software there has been investigated possibility remain control on visible and invisible parties of terrain on supervision line from supervision point to target point.

2. TERRESTRIAL PHOTOGRAMMETRY TECHNOLOGY

The principal application of photogrammetry is to determine the spatial position of the natural and fabricated objects situated on the earth's surface (topographic application). According to the location of the sensor during data acquisition, there are three branches of photogrammetry: Terrestrial photogrammetry means that a ground based stationary sensor acquires the images. Aerial photogrammetry deals with images taken with sensors mounted on airborne platforms. Space photogrammetry embraces the processing of images recorded of the earth or of other planets from satellites.

Mathematical modeling can perform photogrammetric operations. This method is called analytical, numerical or computational photogrammetry.

Nowdays, the most of maps are made on the basis of EARS aerospace photographs. And the photogrammetry technology is one of the most important tools for development these aerospace photographs. An application of photogrammetry technology [4] provides an icreasing of effectiveness of the combat operation organization, an icreasing of operability of the decision making, pass ahead of enemy during development of information etc.

For the purpose of construction of the terrestial orthophotomap and 3D-model the photogrammetry technology is used in mapping. But efficiently determination of coordinats is based on the video surveillance, and for the present this technology isn't fully investigated and improved. Photographies camera development involves next stages: collection photographies in one space by use of the coordinates of projection centers, inclusion the reference points with precise coordinates and show these points in photographies, determination of averaged connecting points between photographies, determination of the parameters of external orientation, construction and balancing of the space aerophototriangle network. After completion of these processes by use of photogrammetry cutting it is possible to determine of the coordinates of some point, to obtain 3D layouts of the objects, to construct of digital model of the relief, to obtain the error-free, connected and reduced to coordinat system orthophotoplane

That to obtain a high accuracy, before to make photography the photographic camera must be calibrate. It is known that there is a distortion in lens of photographic camera. This distortion is higher in small format consumer photographic cameras and so, there are large geometrical errors in obtained photographies.

Coordinates define the relative position of points in space in a reference system. Frequently used reference systems are the:

• *polar* coordinate system τ, θ in a two-dimensional space);

• *geodetic* (geographic) coordinate system (latitude ø, longitude λ and the height above the ellipsoid h);

• *Cartesian* (rectangular) coordinate system (X, Y, Z).

Most photogrammetric operations are performed in a right-handed Cartesian coordinate system.

At first of all, the external and reciprocal oriented parameters of pair of photographies are determined [5,6]. This, there are the values determined positions of photographies in the space in the moment of shooting (fig. 1): here, X_{S1}, Y_{S1}, Z_{S1} are the coordinats of projection center of a left photography; X_{S2}, Y_{S2}, Z_{S2} are the coordinats of projection center of a right photography; α_1, α_2 are the lengthwise slope angles on the S_1XZ and S_2XZ planes of the left and right photographies; ω_1 and ω_2 are the breadthways slope angles on the S_1o_1Y and S_2o_2Y planes of the left and right photographies; χ_1 and χ_2 are rotation angles of left and right photographies [2].

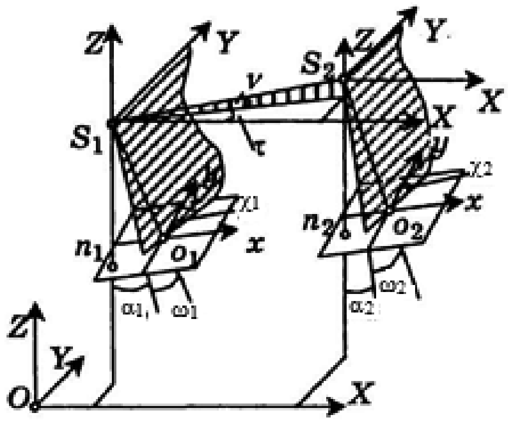

Fig. no.1. *External oriented parameters of pair of photographies.*

If we calculate a difference of external oriented elements of the left and right photographies then we can calculate a mutual oriented:

$$\left.\begin{array}{c} B_X = X_{S2} - X_{S1}, B_Y = Y_{S2} - Y_{S1}, B_Z = Z_{S2} - Z_{S1} \\ \Delta\alpha = \alpha_2 - \alpha_1, \Delta\omega = \omega_2 - \omega_1, \; \Delta\chi = \chi_2 - \chi_1 \\ tg\tau = {}^{B_Y}/_{B_X}, \; sin\nu = {}^{B_Z}/_{B} \end{array}\right\}$$

All of these procedures are made fully for all photographies. The model generated called a block (fig. 2).

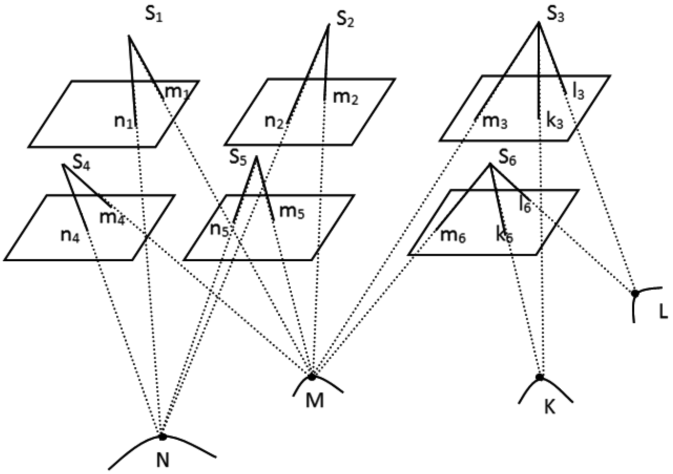

Fig. no. 2. *Photogrammetry block.*

The triangulation calculations in this block are fully balanced [7]. The balancing is carried out with mutual of least square technique. The balancing block is used for determination of parameters complex which find more precisely the coordinates of measured points between possible photographies. Let us assume, that there are n points in m photographies, and Xi,j is the projection of i point in the j photography. In depending on disposition i point on the j photography we have

$$\nu = \begin{cases} 1, i \in j \\ 0, i \notin j \end{cases}$$

If we adopt, that each j camera is parametrized by aj vector and each i 3D-point is parametrized by bi vector then balancing principle is:

$$\min_{a_j, b_i} \sum_{i=1}^{n} \sum_{j=1}^{m} \nu_{i,j} d\left[Q\left(a_j, b_i\right), x_{i,j}\right]^2$$

Here: Q(aj, bi) is expected projection of i point on the j photography, d(x,y) is a distance between photography's points described by x and və y vectors. As we can see that a balancing block leads to minimum of project errors. Then, the precise geodesic coordinates of the points of block net and the external orientation parameters of photographies are determined.

After determination of the internal orientation elements, the distortion parameters, the external orientation elements and the mutual orientation elements we can determine the coordinates of any points on the photography by straight photogrammetry cutting method. The sense of a photogrammetry cutting method is next. Let us, m1 and m2 are images of some M point of territory on P1 and P2 photographies shooted from out of S1 and S2 centres (Fig. 3).

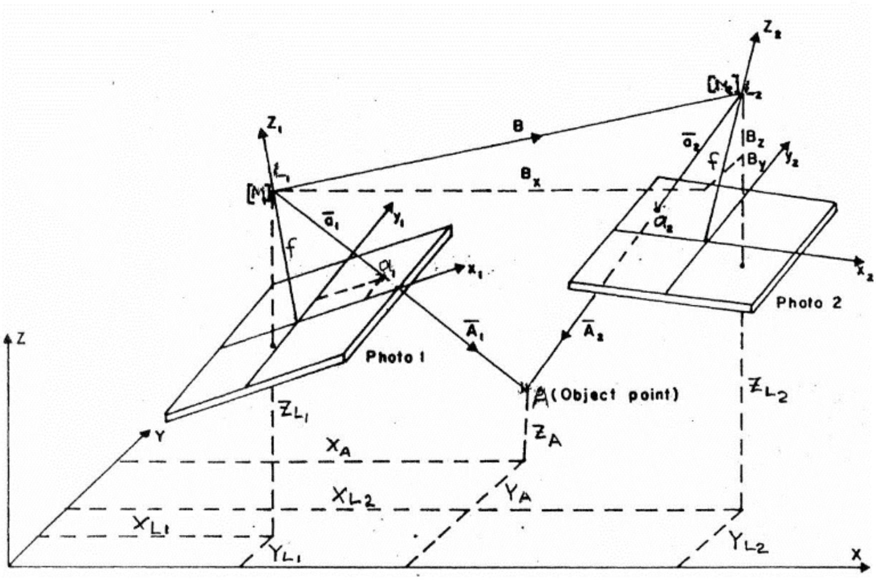

Fig. no. 3. *Straight photogrammetry cutting*

It is need to determine the coordinates of *A* point in *OXYZ* sistem (if the positions of photographies relative to this system). For this we must to solve below system of equations:

$$\left.\begin{aligned} X_A &= X_{S_1} + N_1 X_1 = X_{S_1} + B_X + N_2 X_2, \\ Y_A &= Y_{S_1} + N_1 Y_1 = Y_{S_1} + B_Y + N_2 Y_2, \\ Z_A &= Z_{S_1} + N_1 Z_1 = Z_{S_1} + B_Z + N_2 Z_2 \end{aligned}\right\}$$

Here:

$$\left.\begin{aligned} N_1 &= \frac{B_X Y_2 - B_Y X_2}{X_1 Y_2 - Y_1 X_2} = \frac{B_X Z_2 - B_Z X_2}{X_1 Z_2 - X_2 Z_1} = \frac{B_Y Z_2 - B_Z Y_2}{Y_1 Z_2 - Z_1 Y_2}, \\ N_2 &= \frac{B_X Y_1 - B_Y X_1}{X_1 Y_2 - Y_1 X_2} = \frac{B_X Z_1 - B_Z X_1}{X_1 Z_2 - X_2 Z_1} = \frac{B_Y Z_1 - B_Z Y_1}{Y_1 Z_2 - Z_1 Y_2} \end{aligned}\right\}$$

B_X, B_Y and B_Z are the coordinate differences beween projection centres.

3. TERRAIN ORTHOPHOTOMAP MAKING

By indicated above principle in depending on sizes of photographies pixels we can determine the coordinates of any point of a surface of the compact terrain or object. By-turn, this produces a cloud of points. And it means 3D model of territory. But, this work takes a long time: in depending on a quality of photography, a number of photographies and a terrain size it takes from several minutes to several hours.

Most photographic rectification is performed in order to produce rectified aerial photographs which have been brought to some uniform scale in order to produce high-quality mosaics. Photographic rectification is used also to produce scaled photomaps of fiat-laying terrain in lieu of producing more expensive orthophotographs and orthophoto mosaics. In both of these applications, a continuous tone picture of the ground is needed.

By using shooted photographies we can construct orthophotomap of terrain. The mean of orthophotomapping is a joining of the several photographies. But, therewith the center of shooting is created by a projection method, the errors are arised therewith the differences of heights of the relief or other terrain objects on the photographies (fig. 4). That is, because of differences of heights the points are projected in false coordinates.

We can avoid these errors by using of 3D model of terrain (fig. 5) or digital model of relief. On the next stage these errors free any photography is joined and then we obtain orthophotomap or orthophotograph [7].

The orthophotomap making is took some time. But at last time, by use (or not use) ready digital models of relief in some softwares it is possible orthophotomap making during a very short time (with a relatively low precision) on the basis of obtained photographies, by-turn, it increases an application availability shooted photographies by drons in combat operations (fig. 5) [2].

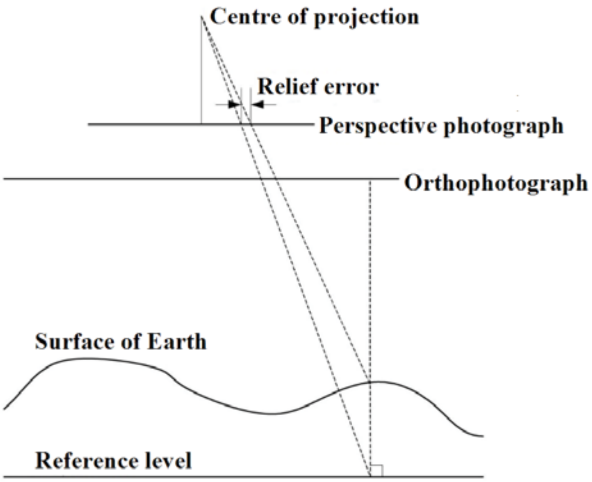

Fig. no. 4. *The error produced by relief effect*

Fig.no. 5. *3D-model of terrain*

4. CONSTRUCTING TERRAIN PROFILE BY GIS TECHNOLOGY

GIS technology is one of the latest modern method to screening condition in digital environment. E.g. Geographical analyze was conducted to study screening condition in GIS environment of a terrain of Azerbaijan by applying ArcGIS 10.3. application of ESRI company [8,9]. 3D Analyse and Spatial Analyse instruments of the program application were used on this purpose.

ArcGIS – ESRI belongs to the U.S. geoinformation program products company. It is applied in cadastral, registraion of real estate, engineering communication systems, geodezy and utilization of undergroud sources. ArcGIS branded products are classified into table and server products.

Either of key products of a tabletop coordinate measuring machine, ArcView, ArcEditor, ArcInfo combines in itself the functional characteristics of previous product. The key server product - ArcGIS for Server is considered for publication of internet interactiv maps and geoinformation projects which have centralized memory and unlimited vacancies. Imageserver produc is released for publication of big voluminous raster information, ArcSDE is intended for storage of spatial data in UVBS (unificated base system) and for integration with other data systems.

With the help of the mentioned technology, it is possible to select opportune height providing better observation, to determine visible and unvisible area of the very terain, determination of various areas and objectives towards the activity trajectory as well as the pathes the enemy is expected to approach.

It is possible to study observation condition of terrain in a short period of time by means of GIS technology. By ArcGIS application, it is possible to calculate the coordinates of starting and ending points of visible and invisible area along the straight sight (width, longtitude and altitude) and the range from the observation point to a given point, etc.

Line of sight analyze is used by applying 3D analyst module of ArcGIS application. In this analyse geographical analyse is conducted to identify visible and invisible areas wile observing from observation point (A) towards target point (B).

Mountainous area with 2598 meters absolute altitude is selected to conduct geographical analyze. Two points of which approximate altitude is known: observation point (*A*) and target point (*B*) are defined. Absolute altitude of observation point is 2951 meters, the absolute altitude of the target is 2198 meters. Relative altitude of the points comprises 753 meters. Our purpose is to define visible and unvisible areas along the straight line between the observation point (*A*) and the target point (*B*).

The first of all, the classification of relief on altitude model of the area is implemented [10]. A modern sattelite technology is used to design digital altitude model of the area [11,12,13]. It is possible to design inclination and relief exposition maps and 3D models of terrain, to print out terrain profile and analyzes whether we are observable as well as volume analyse by means of digital altitude model (Fig. 6).

With the help of profile given in Fig. 7 the differentiation of the terrain between observation point (*A*) and target point (*B*) as per ranges and altitudes and visible (green line) and invisible (red line) terrains are easily seen.

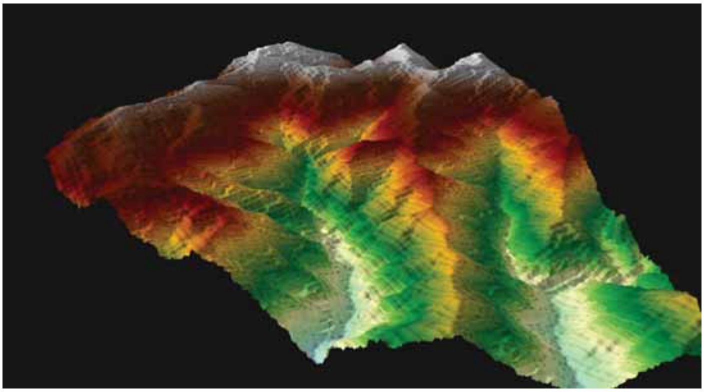

Fig. no. 6. *3D model of prepared relief*

We can have a conclusion from the information we got that the selection for the observation point (*A*) is satisfactory. It gives an opportunity to observe the arrea around point *B*. As it is seen on the template that the terrain of point *B* is totally under control after 3200 meters along the straight line (Fig. 2).

Thus, GIS technology helps in rapid and better understanting of analyze in digital format and in getting precise result close to 100 %. To get more accurate results and to conduct military, strategic planning, the same analyze must be applied from point *B* moving towards point *A*. In this case, screening from enemy positions, it is possible to find out the terrain around point *A* which is under hostile observation and thus military planning tactics could be implemented accordingly.

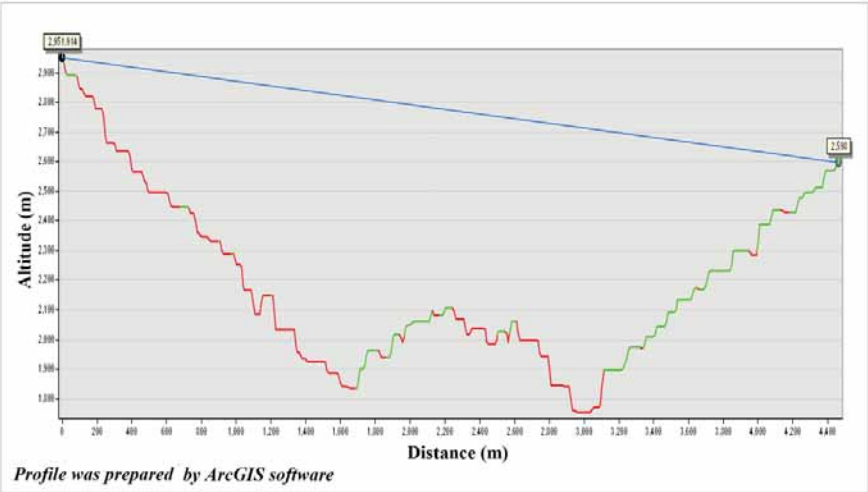

Fig. no. 7. *Altitude profile of visible and unvisible areas along the line between A and B points*

5. CONCLUSIONS

At the conclusion, we can note that for terrain battle reconnaissance the military application of geographic information system and photogrammetry technologies can be implemented if, first of all, photogrammetry specified photographing carry out, shooted photographies in real-time mode are sent by the radio communication to center, an operator implements efficiently the terrain orthophotomap making (determination of coordinates of the sought-for stationary object, efficiently decision making etc.) or constructs the terrain detailed 3D model for orginization in future the battle operations and combat control.

Tthere has been constructed 3D model for choosen mountainous terrain of Azerbaijan Republic using GIS technology. There has been obtained a terrain profile and carried out mapping. Using ArcGis software there has been investigated possibility remain control on obserbvable and unobservable parties of terrain on supervision line from supervision point to target point.

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