

## Integration of Photogrammetry and Geographic Information System (GIS) in Digital Mapping Production

Afrah M. Daham\*

Received on:16/3/2010

Accepted on:4 /11/2010

### Abstract

This research introduce the utilization of Geographic Information System (GIS) and photogrammetry in digital map production. An aerial stereopair was used to produce an orthophoto by ERDAS LPS software. The Arc GIS software then used to prepare a digital map with multi layers for that study area. The produced map could be used and updated any time by GIS software. The research proved its effectiveness for integrating the GIS and photogrammetry in digital mapping since it is a time and cost consuming technique when it is compared to the conventional methods. Also the resulted accuracy ((Root Mean Square Error (RMSE)) was (35) cm which was suitable for large scale mapping.

**Keywords:** Geographic Information System (GIS), Digital Photogrammetry, Orthophoto, Stereopair, Root Mean Square Error (RMSE).

### تكامل المسح التصويري ونظم المعلومات الجغرافية في انتاج الخرائط الرقمية

#### الخلاصة

يقدم هذا البحث كيفية استخدام نظم المعلومات الجغرافية (GIS) والمسح التصويري في انتاج خارطة رقمية، تم الاستعانة بزواج من الصور الجوية الرقمية المتوفرة لمنطقة معينة ومن ثم تحويلها الى صور ذات اسقاط عمودي (orthophoto) بالاستعانة ببرنامج ERDAS LPS وباستخدام برنامج Arc GIS بملحقاته المتعلقة بأعداد خارطة رقمية متعددة الطبقات (layers) لمنطقة الدراسة. ان الخارطة المنتجة يمكن الاستفادة منها والرجوع اليها في اي وقت وتحديث اي بيانات فيها باستخدام برامج نظم المعلومات الجغرافية. لقد اثبت البحث فعالية تكامل المسح التصويري ونظم المعلومات الجغرافية في انتاج الخرائط الرقمية وذلك بسبب اختصار الوقت والكلفة اذا ما قورنت بالطرق التقليدية كما ان الدقة المستحصلة (RMSE) كان (35) سنتمترا والذي يعتبر ملائما لانتاج الخرائط ذات المقاييس الكبيرة.

### 1.1 Introduction

We are living in a period of very rapid technological change. In photogrammetry and Geographic Information System (GIS), this is mainly the result of the recent explosion in information technology and is closely correlated with the general development of science and engineering. Looking back over the last few decades in photogrammetry

and GIS, we can distinguish great developments in several areas. The general development, in particular electronics and computer technology, undoubtedly has opened up new advances in photogrammetry and GIS in the areas of instrumentation, methodology, and integration, many fields in surveying and photogrammetry are now become

applicable like the production of digital maps [5].

The production of maps by photogrammetry using the traditional methods of stereo plotting device takes much time and efforts. This research introduce a simple and efficient method for producing digital map depending on the superior facilities available in Arc GIS program, and so it provides digital map performance and at the same time a low cost one when compared with others produced by any conventional method and other costly software.

The integrating photogrammetry and Geographic Information System (GIS) is an important and interesting field for many engineering applications, as attested by the large volume of published literature. The relevant work may be summarized as follows:

**Mohd Din M. A. and Ahmad M. Y. (2006)**, studied the integration of Geographic Information System (GIS) and digital photogrammetry in Building Space Analysis, concluded the effectiveness of Digital Photogrammetry and Geographical Information System (GIS) in producing a map to show the distribution of space usage in higher learning institution. This research has successfully shown that the digital photogrammetry method is able to capture digital data much faster and accurately. The combination of digital photogrammetry and GIS technology has proven to be the best choice in optimizing the space usage. This technique increases productivity at low cost as well as serves as a very useful tool for planning purposes [7].

**Yeou Rau J., et al., (2007)**, presented a study about the

integration of GIS, GPS and photogrammetry for texture mapping in photo realistic city modeling. The experimental results indicate that the proposed approach is efficient due to a complex building could be treated in one process and multi-face texturing is designed thus the number of pictures can be reduced. Additionally, a large quantity of pictures can be managed efficiently by GPS-Photo-GIS integration [8].

**Ebadi H. and Ahmadi F. F. (2008)**, presented the technique of On-line Integration of Photogrammetry and GIS to Generate Fully Structured Data for GIS. They design and develop of a software package called Online Integrated Photogrammetric GIS (OIPGIS). It was successfully implemented for the first time. This system overcomes mentioned problems in off-line approach, and saves time and cost of spatial data production significantly [7].

### 1.2 Methodology

In this study, Arc GIS and ERDAS LPS software was used to produce the digital map. The experimental work was devoted contain two steps: digital orthophoto production and digital map production.

#### 1.2.1 Digital Orthophoto Production

Digital orthophotos are scale correct aerial photographs. Conventional aerial photographs have limited use for making measurements because they are not true to scale. When looked at the center of an aerial photograph, the view was the same as if looking straight down from the aircraft. However, the view of the ground toward the edges of the photograph was from an angle. This is called a central perspective

projection; scale was true at the very center of the aerial photograph, but not elsewhere. In order to create a scale correct photograph that can be accurately measured an orthographic projection is necessary, in which the view was straight down over every point in the photograph [4].

In this study the procedure used to create digital orthophotographs, called digital orthorectification, was required aerial photography, Ground Control Points (GCPs) for that study area and an associated Digital Elevation Model (DEM) as inputs, but in this study constant elevation value was used (903.813) m instead DEM. The DEM surface was used to orthogonally rectify the scanned raster image file. By combining the DEM and raster image, each image pixel was attributed with a known location and intensity value.

In the rectification process was used computer software to rectify digital images; digital orthophoto production was depended upon a mathematical technique to determined and eliminated geometric distortion. The digital orthorectification was included the following steps:

- Perform interior orientation elements: The internal geometry of a camera was defined by specifying the following variables: principal point, calibrated focal length and fiducial marks.
- Determine exterior orientation elements: In the rectification process, the intensity value for each pixel was resampled using a space resection technique that was commonly used to determine the exterior orientation parameters associated with one

image or many images based on known Ground Control Points (GCPs). Space resection was based on the collinearity condition equations as shown below [2]:

$$x_p - y_o = -f \left[ \frac{m_{11}(X_p - X_o) + m_{12}(Y_p - Y_o) + m_{13}(Z_p - Z_o)}{m_{31}(X_p - X_o) + m_{32}(Y_p - Y_o) + m_{33}(Z_p - Z_o)} \right] \dots(1)$$

$$y_p - y_o = -f \left[ \frac{m_{21}(X_p - X_o) + m_{22}(Y_p - Y_o) + m_{23}(Z_p - Z_o)}{m_{31}(X_p - X_o) + m_{32}(Y_p - Y_o) + m_{33}(Z_p - Z_o)} \right] \dots(2)$$

where:

$x_o$  and  $y_o$ : represent the image coordinates of the principal point.

$x_p$  and  $y_p$ : represent the image coordinate of the point.

$X_p$ ,  $Y_p$  and  $Z_p$ : ground coordinates of point P.

$X_o$ ,  $Y_o$  and  $Z_o$ : ground coordinates of exposure station.

$f$ : calibrated focal length.

$m_{11}$ ,  $m_{12}$ ,  $m_{13}$ ... Element of rotation matrix

Collinearity condition specifies that, for any image, the exposure station, the ground point, and its corresponding image point location must all lie along straight line, thereby being collinear. **Figure (1)** illustrates the elements of exterior orientation.

If a minimum number of three GCPs are known in the X, Y, and Z direction, space resection techniques can be used to determine the six exterior orientation parameters associated with an image. Space resection assumes that camera information is available. Using the collinearity condition, the positions of the exterior orientation parameters are computed. Light rays originating from at least three GCPs intersect through the image plane through the image positions of the GCPs and

resect at the perspective center of the camera or sensor. Using least squares adjustment techniques, the most probable positions of exterior orientation can be computed. Space resection techniques can be applied to one image or multiple images.

Space forward intersection is a technique that is commonly used to determine the ground coordinates X, Y, and Z of points that appear in the overlapping areas of two or more images based on known interior orientation and known exterior orientation parameters. The collinearity condition is enforced, stating that the corresponding light rays from the two exposure stations pass through the corresponding image points on the two images and intersect at the same ground point. **Figure (2)** illustrates the concept associated with space forward intersection [3].

Space forward intersection techniques assume that the exterior orientation parameters associated with the images are known. Using the collinearity equations, the exterior orientation parameters along with the image coordinate measurements of point  $p$  on Image 1 and Image 2 are input to compute the  $X_p$ ,  $Y_p$ , and  $Z_p$  coordinates of ground point  $p$ .

- Compute relief displacement: Relief displacement was corrected by taking each pixel of a DEM and finding the equivalent position in the image. A brightness value was determined for this location based on resampling of the surrounding pixels. The brightness value, elevation, and exterior orientation information are used to calculate the equivalent location in the orthoimage [1]. Relief

displacement can be calculated from the equation (3) as follow:

$$d = \frac{rh}{H} \quad \dots\dots(3)$$

where:

r: can measured directly by the software.

h: given as a DEM file for the study area or as a constant elevation if the area containing minimal relief variation.

H: taken the Z component of the exposure station.

- Resampling: The final step in the orthorectification process is to create the output file. Since the grid of pixels in the source image rarely matches the grid for the reference image, the pixels are resampled so that new data file values for the output file can be calculated. Resampling methods are: Nearest neighbor, Bilinear interpolation and Cubic convolution. Thus removing image displacements caused by central perspective projection, camera tilt, and terrain relief. The individual photographs are then clipped and seamlessly joined together over the entire study area. The resulted was a digital image that combined the image characteristics of a photograph with the geometric qualities of a map a true to scale photographic map However, the accuracy of the final digital orthophotograph was depended in large part on the point density of the digital elevation model [1].

### 1.2.2 Digital Map Production

In this study, after the production of orthophotos for that study area stereopair of the final form the Arc GIS software were used to prepare a digital map with multi

layers for that study area, the layers which was formed: roads layer, woods layer, residential sectors layer, sport fields layer, parking layer, sub roads layer, gardens layer and urban places layer. After the completion of the drawing layers have been producing digital map in its final form and scale of 1:10,000 was appropriated for this scale to the scale of digital aerial photographs that were used in the production of orthophotos which in turn was to be used to produce the digital map, fourteen points were selected as check points to compute the resulted accuracy Root Mean Square Error (RMSE) by using the following equations [3]:

$$R_i = \sqrt{R_{x_i}^2 + R_{y_i}^2} \quad \dots\dots(4)$$

Where

- $R_i$ : The RMSE for check point ( $i$ ).
- $R_{x_i}$ : The X residual for check point ( $i$ ), (the distance between the source and the transformed coordinates in x direction).
- $R_{y_i}$ : The Y residual for check point ( $i$ ), (the distance between the source and the transformed coordinates in y direction).

Depending upon the residuals, the RMSE in X coordinate, the RMSE in Y coordinate, and the total RMSE can be computed from the following equations:

$$R_x = \sqrt{\frac{1}{n} \sum_{i=1}^n R_{xi}^2} \quad \dots\dots(5)$$

$$R_y = \sqrt{\frac{1}{n} \sum_{i=1}^n R_{yi}^2} \quad \dots\dots(6)$$

$$R_T = \sqrt{R_x^2 + R_y^2} \quad \dots\dots(7)$$

Where:

- $R_T$  : total Root Mean Square Error (RMSE).
- $n$  : number of check points.

**Experimental Work**

The experimental work in this study was devoted to contain two steps:

**The first step** is to generate orthophoto from aerial stereopair for an area in Canada as shown in below figure (3) [6]. The photos were provided with information about a scattered fourteen Ground Control Points (GCPs) whose rectangular coordinates (X, Y, Z) are known and permarked on the photo clearly.

**Table (1)** illustrates the ground rectangular coordinates of the fourteen ground control points.

Also the interior orientation elements of two photos are known and as follow:

- Calibrated focal length (f) equal (153.167) mm.
- Coordinate of principal point (p.p) in (mm):  
 $x_o = 0.001$  ,  $y_o = -0.053$
- Fiducial mark calibration coordinates as shown in **Table (2)**.

The production of digital orthophoto process needs to perform orthorectification process that removes the geometric distortion inherent in imagery caused by camera orientation, topographic relief displacement, and systematic error associated with imagery and then projecting the data onto a plane and making it conform to map projection system. Orthorectified images are planimetrically true images that represent ground objects in their true "real world" X and Y position. By

performing space resection, the effects of camera orientation have been considered and removed. By defining a DEM or constant elevation value (ideal for use in areas containing minimal relief variation), the effect of topographic relief displacement can be considered and removed.

In this research the digital orthorectification by ERDAS LPS software involves the following general steps:

1. Data prepare: in this stage the image converted from (jpg) extension to (img) extension so ERDAS LPS become ready for orthorectification..

2. Display camera image: before continued with geometric correction, it must be first make sure that the image did not already have a map model.

3. Start geometric correction Tools: The geometric correction tool in ERDAS LPS contain four icons that will be used to complete the orthorectification process. These icons are: camera model properties, GCPs tools, resampling and calibrate.

4. Enter the camera model properties: in this step the elevation, interior orientation elements, estimated value of exterior orientation, and projection information will be entered are illustrated in **Figure (4)**. These information's can be add as follow:

- *Set camera model properties.*
- *Edit Fiducial.*
- *Enter estimated value of exterior orientation.*
- *Add projection information.*

An error of less than 1.0000 pixels is acceptable. An error of greater than 1.0000 indicates that the points were inaccurately measured or poorly identified. But in this study the

resulted accuracy Root Mean Square Error (RMSE) was (0.0075) which was very acceptable.

5. Record the ground control points (GCP's): in this step ground control points will be digitized and reference coordinates will be entered for these points, also the resulted accuracy Root Mean Square Error (RMSE) for the X and Y values was (0.32) m which was within acceptable limits.

6. Resample the image: in this step the transformation matrix will be calculated and new pixel grid will be created.

The exterior orientation parameters for the left and right photos were computed by the concept of space resection technique using collinearity condition equations as described in section 1.2.1 are listed as follows:

Exterior orientation parameters of the left photo:

Omega	=	-0.9989	+-
		0.3386 deg	
Phi	=	0.8292	+-
		0.0820 deg	
Kappa	=	92.1082	+-
		0.0562 deg	
XL	=	676813.0056	+-
		2.1245 m	
YL	=	7184193.4867	+-
		5.7364 m	
ZL	=	1903.5593	+-
		3.3294 m	

Exterior orientation parameters of the right photo:

Omega	=	-1.1792	+-
		0.4620 deg	
Phi	=	1.6746	+-
		0.0800 deg	
Kappa	=	91.9686	+-
		0.0244 deg	
XL	=	676811.7688	+-
		1.5979 m	
YL	=	7184752.5385	+-
		7.8628 m	

ZL = 1886.2806 +-  
0.3967 m

In this step the images have been ortho resampled as shown in **Figure (5)** and it can be checked how well they fit together.

**The second step** is to produce a digital map from orthophotos which was produced previously in the first step of experimental work. The Arc GIS software was used to provide a digital map with multi layers for that study area. The layers which were formed were eight layers are: layer of buildings, layer of roads, layer of woods, layer of parking, layer of sport fields, layer of gardens, layer of sub roads and layer of status. **Figures (6) and (7)** illustrate the drawings of some of these layers (roads and woods).

After the completion of the drawings layers. the digital map in its final form with a scale 1:10000, were produced as shown in Figures (8) and (9).

Fourteen point were selected for the checking the accuracy in digital map, the resulted accuracy ((Root Mean Square Error (RMSE)) computed by using a special equation (7) as described in section (1.3.2) was (35) cm which was suitable for the production of large scale mapping.

The selected scale map is suitable and appropriate for the scale of aerial photographs that have been used in the production of the map, and the possible use of the map produced and used at any time possible and update its data using Geographic Information System (GIS) software.

### Conclusions

1. In conclusion, this study has proven the effectiveness of integration photogrammetry and

Geographic Information System (GIS) in digital map production. This research has successfully shown that the integration of photogrammetry and GIS method is able to capture digital data much faster and accurately. This technique increases productivity at low cost as well as serves as a very useful tool for planning purpose.

2. The most important is that the digital orthophotos can be used as direct input Geographic Information System (GIS) software.

Single photo can be orthorectify also strip photo can be rectified. The digital orthorectification contain the process of the aerotriangulation and for this we can find the coordinate of any tie pass points.

3. The production of this map through Geographic Information System (GIS) software is easy and effective way, and shorten the time and cost when compared with traditional production methods used in photogrammetry using stereoplotter equipment, one of the very expensive equipment and it requires time and effort as big.

4. The possible use of the digital map produced and used at any time possible and update its data using Geographic Information System (GIS) software.

### References

- [1]. Wolf, R., and Dewitt A., (2000). "Elements of Photogrammetry with Application in GIS", 3<sup>rd</sup> edition.
- [2]. Wolf, R., (1983). "Elements of Photogrammetry", 2<sup>d</sup> edition, McGraw-Hill International Book Company.
- [3]. ERDAS, Inc., (1999). "ERDAS IMAGINE", OrthoBASE Tour Guide, Atlanta, Georgia USA.

- [4].Ecker, R., (1992). " Digital Orthophoto Generation Based on a High Quality DTM " ITC Journal, No.1.
- [5].ESRI, (2001). " What Arc GIS" , Computer program.
- [6].Aerial stereopair of Calgary in canada . Retrieved: october 19, 2009 from [http://www. Library.ucalgary.ca /\\_ madgia / maps airphotos / search airphotos.](http://www.Library.ucalgary.ca/_madgia/maps/airphotos/search/airphotos)
- [7].Abdul-Rhaman A., Zlatanova S., and Coors V. (2006) " Innovations in 3D Geo Information Systems", lectures notes in Geoinformation and Cartography. Retrieved: December 31, 2007 from [http://www.springerlink.com /Berlin Heidelberg/ Digital photogrammetry. Pdf](http://www.springerlink.com/Berlin_Heidelberg/Digital_photogrammetry.Pdf)
- [8].Yeou Rau J., et al., (2007), " integration of GPS, GIS and Photogrammetry for Texture Mapping in Photo - Realistic City Modeling" ISPRS Journal, No.2, Vo.7.

**Table (1) Ground Rectangular Coordinates  
of GCPs (meter).**

<i>Point</i>	<i>X [m]</i>	<i>Y [m]</i>	<i>H [m]</i>
110	676349.506	7184079.099	885.758
3110	676187.214	7184138.610	883.488
3111	676423.413	7184149.085	887.494
3112	676782.089	7184150.526	888.756
3113	676259.424	7184749.781	898.677
3114	676377.925	7184720.718	904.759
3115	676763.528	7184713.331	923.008
4110	677123.559	7184100.303	890.640
4111	677267.560	7184089.381	894.912
4112	677379.258	7184208.899	894.467
4113	677020.416	7184626.978	921.563
4114	677155.718	7184626.399	925.612
4115	677213.374	7184754.621	925.388
4116	677332.347	7184765.561	928.863

**Table (2) Fiducial Mark Coordinates.**

<b>Point</b>	<b>X mm</b>	<b>Y mm</b>
1	-105.999	-105.978
2	105.999	106.022
3	-106.018	106.021
4	105.988	-105.978

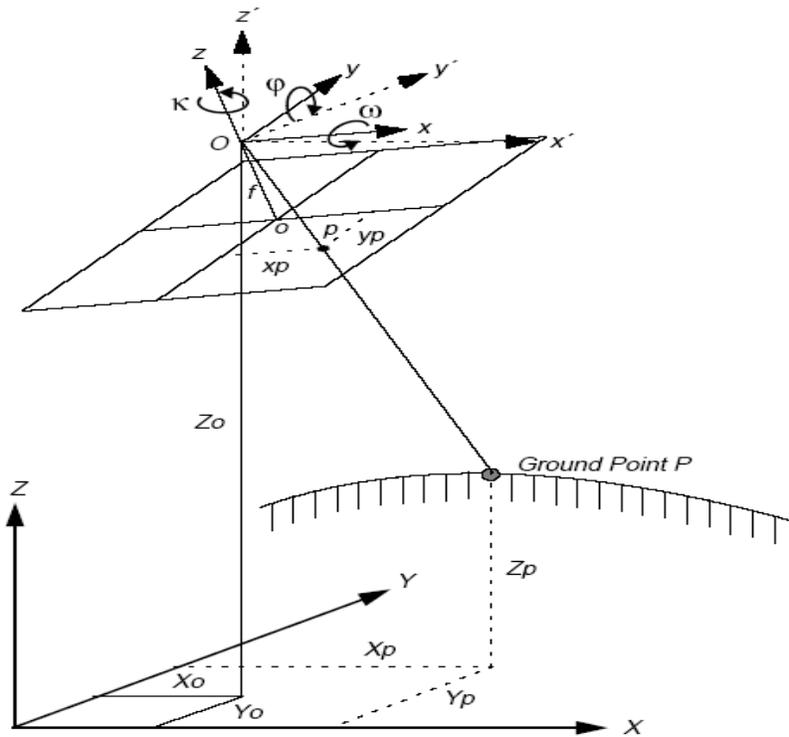


Figure (1) Elements of Exterior Orientation [3].

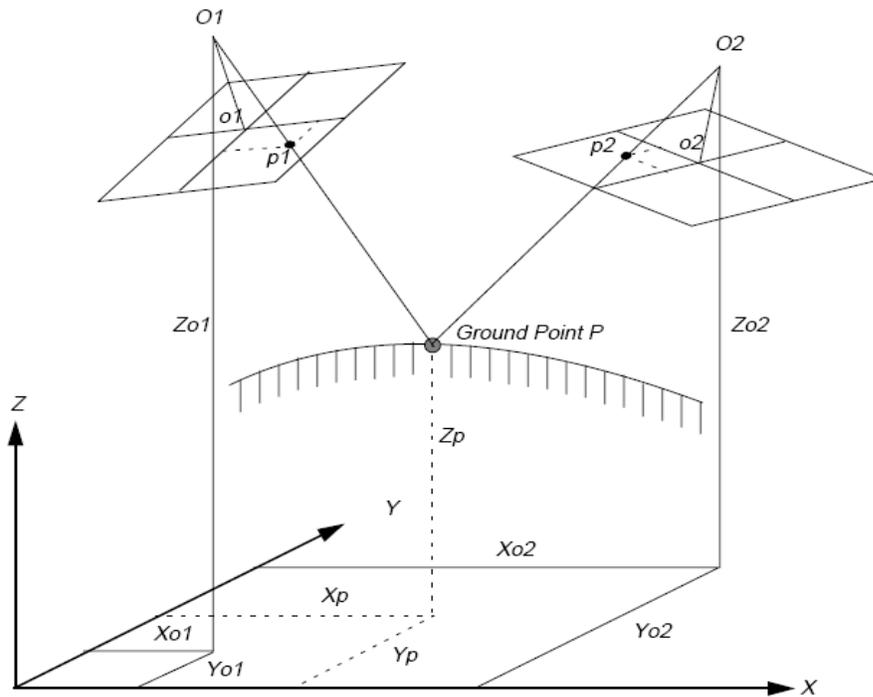


Figure (2) Space Forward Intersection [3].

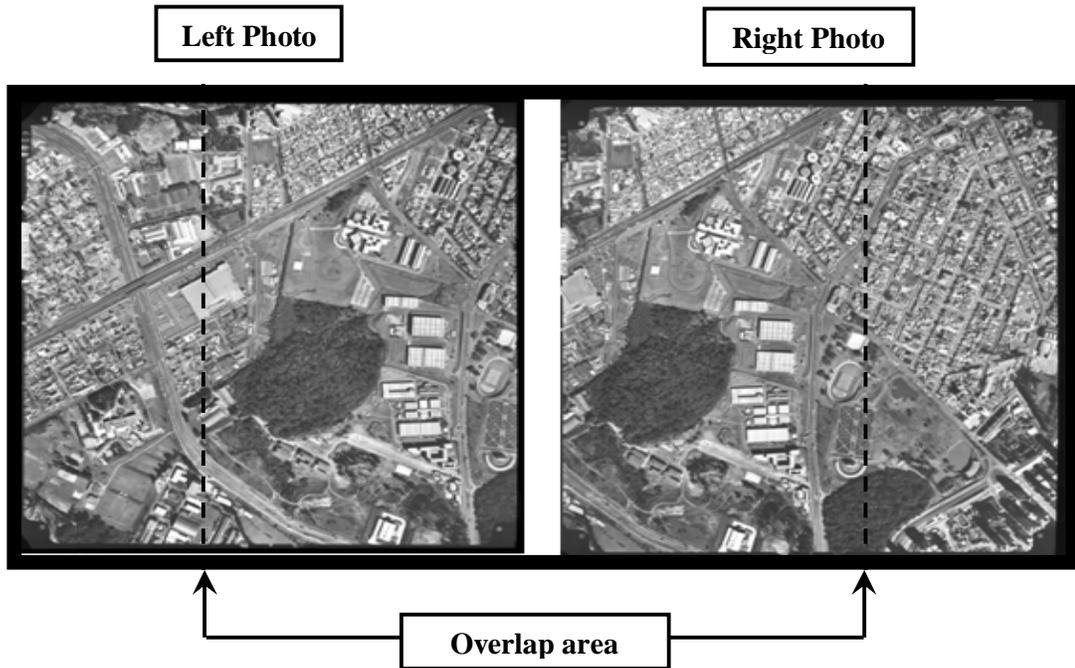


Figure (3) Aerial Stereopair [6].

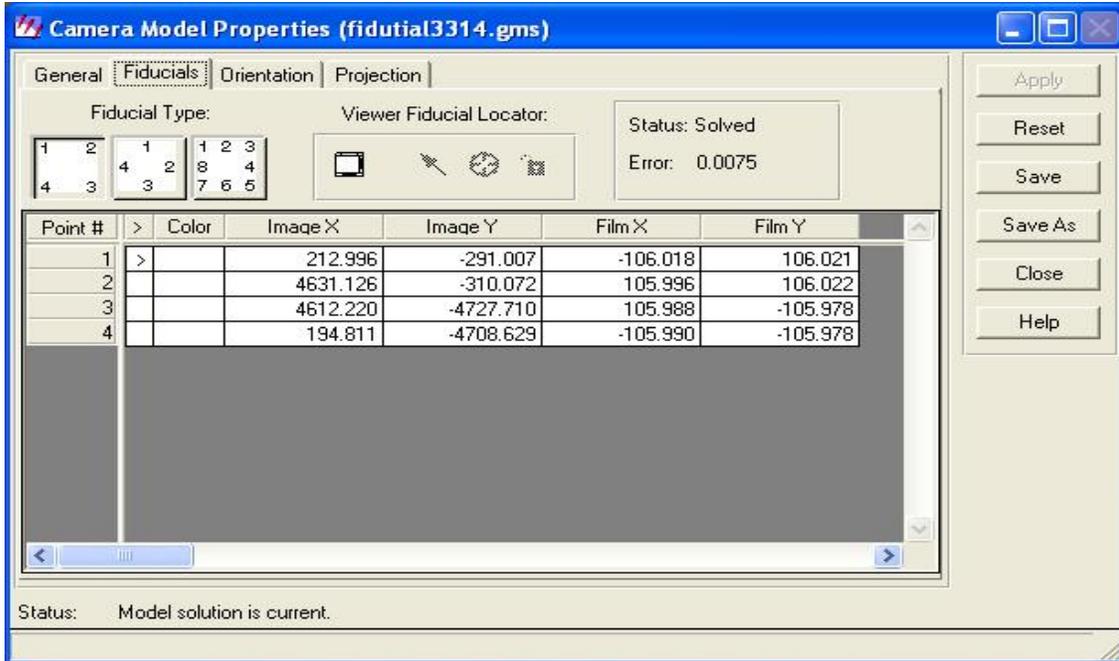


Figure (4) Fiducial Options Dialog.



Figure (5) Finally Orthophoto Images.

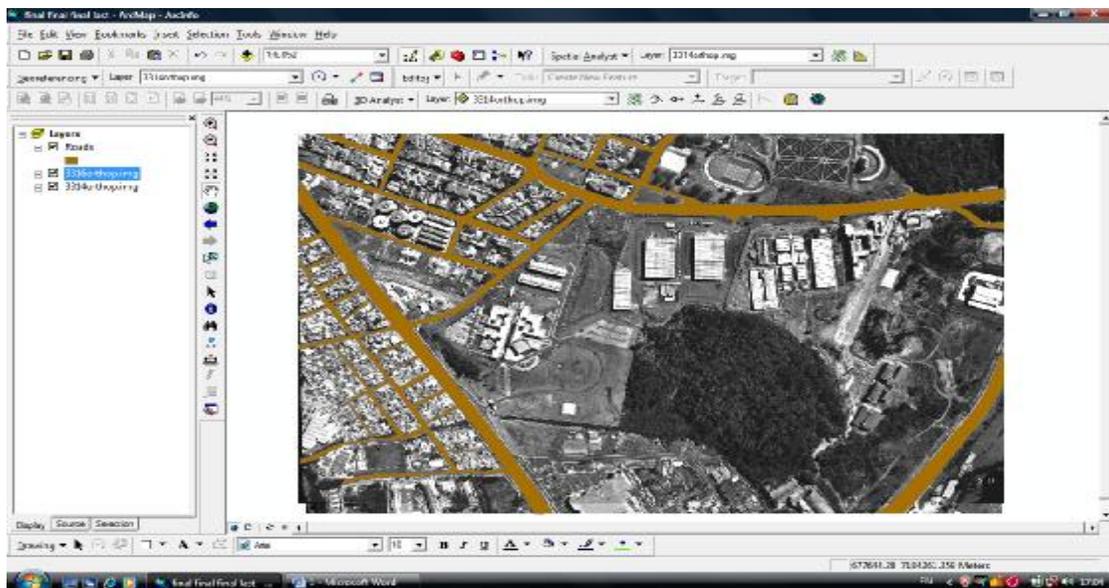


Figure (6) Layer of Roads.

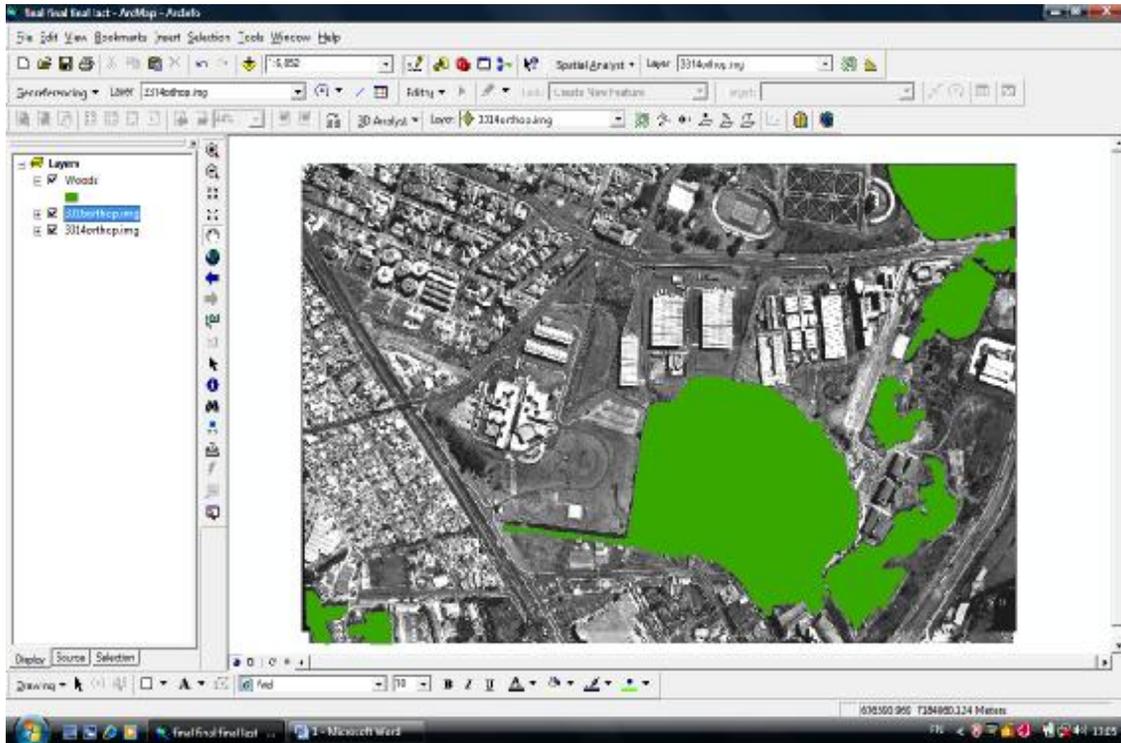


Figure (7) Layer of Woods.

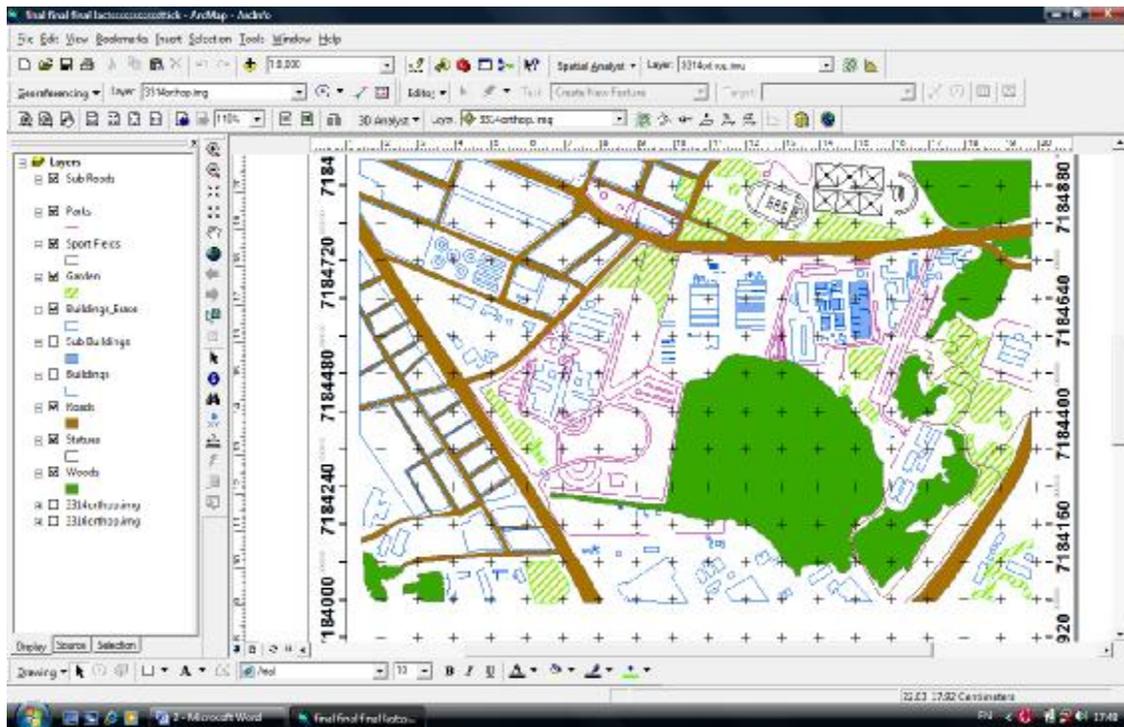


Figure (8) Digital Map in the Interface of Arc GIS Software.

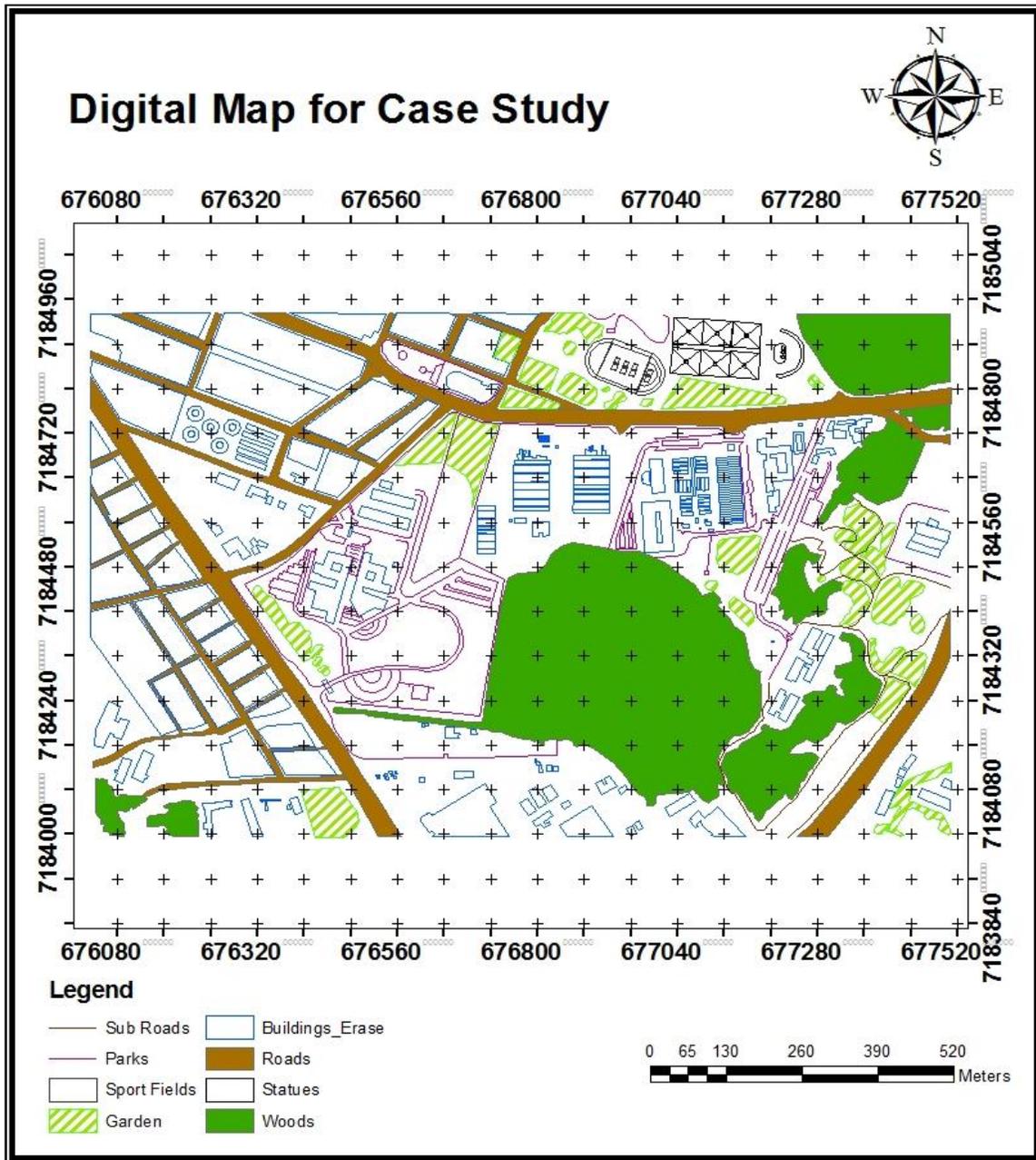


Figure (9) Final Digital Map.