

## Accuracy Assessment of Analytical Orientation Process in Close range Photogrammetry

**Dr. Abbas Zedan Khalaf** 

Building and Construction Department, University of Technology/Baghdad

Email:khalaf1955@yahoo.com

**Dr. Nisreen S. Mohammed**

Building and construction Department, University of Technology/Baghdad

**Farah Saad A. Al-hasoon**

Design Department, Baghdad Municipality/Baghdad

Email:falhasoon@gmail.com

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### ABSTRACT

This paper studies data manipulation using analytical relative orientation process to determine the exterior orientation parameters. This process can be accomplished by two scenarios; the first one is implemented using collinearity condition while the second one is implemented using coplanarity condition. The final results of both scenarios will be a three dimensional (3D) model and in order to specify the more precise scenario in reconstruction of (3D) models Root Mean Square Error (RMSE) for each scenario was computed. Absolute orientation process was used to transform coordinates of the model system into coordinates of the ground system then (RMSE) for each was computed. The difficulty of obtaining Ground Control Points (GCPs) that covers the photogrammetric project had been overcome by establishing a Portable Control System (PCS). This (PCS) is a block made of an Aluminum alloy that had been shaped by a (TNC) milling machine to produce plane surfaces on it. The points of intersection of the produced surfaces on the block was labeled or coded and the distances between these points were measured manually by the digital vernier caliper 150mm and micrometer. These points represented control points in the captured images also a specific point within the block was chosen to be the center of this control system and all the remaining points was calculated with reference to it. The calculated (RMSE) for collinearity condition was 1.0212 mm. while for coplanarity condition was 1.0230 mm. So the precision of both models is nearly identical moreover coplanarity condition was more feasible for the requirements of close range photogrammetry.

**Keywords:** Close range Photogrammetry, Collinearity Condition, Coplanarity Condition, Exterior Orientation Parameters, and Initial Values Relative Orientation.

### INTRODUCTION

Orientation is the determination of the position and attitude of camera, image, model, triplet or such a unit in space relative to a system of coordinate reference while Interior Orientation Parameters (IOP) is the recovering of a projected cone of rays that entered the camera lens to make the original exposure. Elements of interior orientation are camera constant also known as principle distance (focal length), location of the principle point and distortion parameters. Exterior Orientation Parameters (EOP) consists of two sets of parameters; they are 3D coordinates giving the location of the perspective center and orientation angles defining the attitude of the camera at the instant of exposure [1].

Relative Orientation is the reconstruction of the same perspective relative situation between images of a pair while Absolute Orientation goes after relative orientation with a process that establish a relationship between the model and ground control coordinate system. Thus analytical computational photogrammetry consists of mathematical modeling of the relationship between different systems like image-ground, image-model and model-ground [1].

Image-based modeling that uses passive sensors (digital cameras) requires a mathematical formulation to transform 2D image coordinates into 3D information. Images contain all the useful information to form geometry and texture for a 3D modeling application. But the reconstruction of detailed, accurate and photo-realistic 3D models from images is still a difficult task, particularly in the case of large and complex sites that have to be photographed with widely separated or convergent image blocks [2].

One of the most difficult challenges in Image-based modeling is the correspondence problem of the images under consideration. It can be implemented by two procedures either automatically or manually for each procedure there are advantages and disadvantages. Within this paper the adopted procedure for finding the corresponding points between two images in order to produce 3D model was the manual procedure.

In the literature a lot of recently presented papers deal with 3D image-based modeling. But most of these papers used the traditional photogrammetric procedures as simultaneous or sequential models for data processing or depended commercial software. Al-Joboouri and Jaber [3] presented 3D models depending on the mathematical models of bundle adjustment and DLT while Aljanabi [4] tested three cases to produce 3D model with using commercial software Photomodeler Scanner (version 6).

Dai [5] established a 3D model of precast façade based on Relative Orientation using Coplanarity Equations and least squares adjustment were applied to compute the relative position and orientation between two camera stations then collinearity equations were used to calculate the spatial coordinates of the model. Furthermore Ahmad and Rabiu [6] applied a photogrammetric procedure to form three dimensional (3D) model for University of Technology Malaysia campus. Erdas IMAGINE, SpacEyes3D Builder, Google SketchUp as well as AutoCAD Map software packages were used. The dimensions of the building were measured (length, width, and height) then the results obtained from this software were compared with the measurements of surveying. Attya and Habib [7] adopted (MSAT) program to run the bundle adjustment and the required ground control points were acquired from an existing mass-block 3D model.

The major subject of this paper is imaging 3D reconstruction using close range images by relative and absolute orientation photogrammetric procedures in two scenarios; the first one is implemented using collinearity condition while the second one is implemented using coplanarity condition.

On the other hand there are some difficulties will be appeared when using close range images in performing 3D reconstruction, such as no systematic circumstances in capturing images as diverse angles and location with respect to the target that result in having a variety in angular field of view also the available information about the target object will mostly be image only and the used cameras are un calibrated (unknown IOP).

### **Methodology**

To have an assessment of analytical orientation process it requires images with correspondences points, Interior Orientation Parameters (IOPs) of the used camera initial approximations for the unknown values, the GCPs that cover the photogrammetric project and sensor size in millimeters. These requirements will be discussed in details below.

### **Capturing Images with Correspondences Points**

The general guidance for close range imaging is described in the (ISPRS, 2010) [8] close range working V/6 report. All imaging work was done with one camera Canon EOS 600D moreover the maximum image size was 5184x3456 pixels. Furthermore the obtained images are in form of convergent pairs which provide 100% overlap and hence more efficient coverage of the object. The focal length was 55 mm with manual setting moreover, the (image stabiliser) mechanisms or (a clip-on backs) was avoided in imaging work to maintain stability where each recorded pixel position must represent a repeatable measurement point and the shutter speed

was  $f/7.1$ . While ISO increased if additional sensitivity is needed in lower lighting conditions for the condition of this study the applied ISO was 6400 with no flash.

The object that had been covered within the captured images is the PCS which was established to overcome the difficulty of obtaining Ground Control Points (GCPs) in the captured images. The couple of images below were used within this study to produce 3D model, capturing situation was,  $B$  the baseline between the two images =1400mm and  $D$  the average camera-object distance=2000mm so that  $B/D$  ratio=0.7 and side -1- of the PCS was appeared in both images.

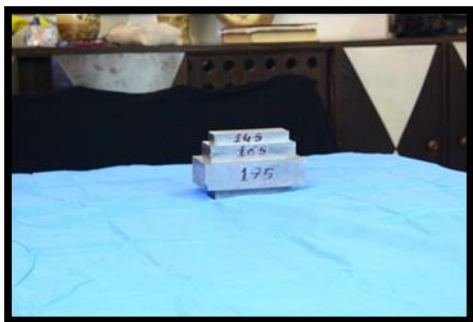


Figure 1: left image

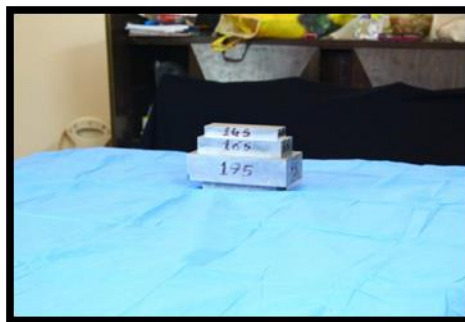


Figure 2: right image

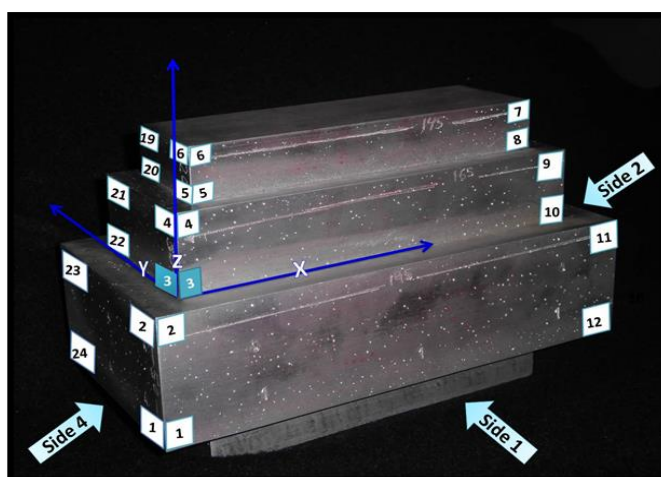


Figure 3: portable control system

### Interior Orientation Parameters (IOPs)

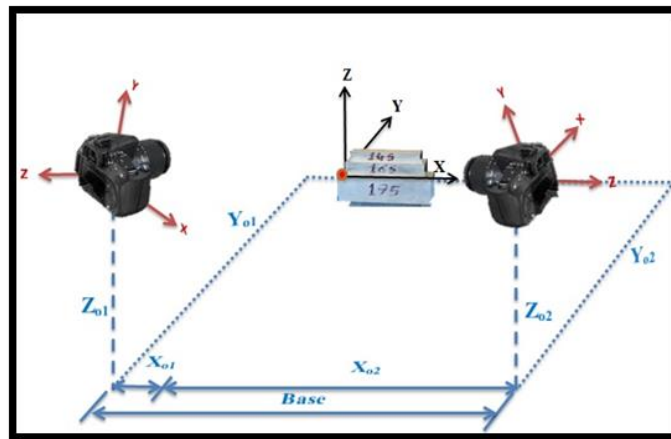
Although IOPs are very important in modeling the systematic errors in image measurements and obtaining accurate metric information from images but this study emphasizes on data processing and not camera calibration moreover ALJanabi [4] is noted that calibration cannot be considered as constant or fixed for non-metric cameras because such cameras have different (IOPs) for each session. Then the (IOPs) must be evaluated in site for calibration matters. Any changes in zooming or focusing require new camera calibration.

### Approach Used to Estimate the Initial Values

Regardless of the way that data processing is implemented whether on the basis of simultaneous or sequential or even relative and absolute orientation methods, there is a principle issue in photogrammetry which is the determination of initial values. These values are used within the iterated solution of the analytical photogrammetric methods also they are of two kinds, the first one is the initial values of Exterior Orientation Parameters (EOPs) while the second one is the initial values of coordinates of the unknown ground points in case of bundle

adjustment method or coordinates of the unknown model points in case of relative and absolute orientation method.

This study adopted a simple way to estimate the initial values based on measurements by a steel tape. As illustrated in (Fig. 4) camera position is measured by a steel tape with respect to the center of the PCS. While the initial values of camera orientation were estimated from capturing situation (roughly). With regard to the initial values of coordinates of the unknown ground points as in the unknown stereo model as in relative orientation with collinearity condition, the author\* applied a developed function which is prepared depending on the basic of using collinearity equation in having ground coordinates



**Figure 4: measuring camera position with respect to the PCS**

### Software Development

The developed software for this study can be divided into two groups depending on its application:

- Image Matching software.
- Photogrammetric software for image 3D reconstruction and Root Mean Square Error (RMS) software to examine the accuracy of the reconstructed coordinates.

### Image Matching Software

The author\* prepared a Matlab script (Generalpicking.m) for two images as maximum number of inputs, this script is based on a Matlab function (ginput) that allows user to obtain information from the image by marking correspondence points by mouse clicks, this function will return (x, y) in pixel coordinates for the selected points. The final result of the script is converting the coordinate system for these points from pixel to metric in other words from upper-left corner coordinate system to center of the image coordinate system.

Moreover General picking m as shown in (Fig. 5 and 6) is contained user interface which facilitates opening and saving the required image (\*.jpg) then marking and coding the desired points in image, maintaining the codes that were shown previously in (Fig. 3)

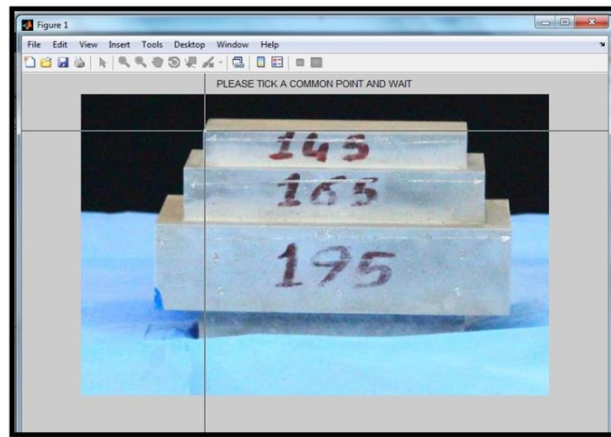


Figure 5: marking points within the image

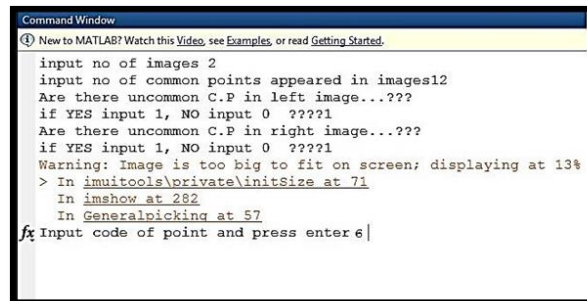


Figure 6: coding points within the image

### Photogrammetric Software for Image 3D Reconstruction

The developed software by author\* can be divided into two kinds depending on the used mathematical model. The first one is (RA-Col). It's a set of functions that implement the principle of relative and absolute orientation with collinearity condition in case of close range photogrammetry and calculate RMSE for the operation (Fig. 7) represents the outlines of the methodology workflow of RA-Col software. While the second one is (RA-Cop) which represents a set of functions that implement the principle of relative and absolute orientation depending on photogrammetry and calculate RMSE for the operation (Fig. 7) represents the outlines of the methodology workflow of RA-Col software. While the second one is (RA-Cop) which represents a set of functions that implement the principle of relative and absolute orientation depending on coplanarity equation in case of close range photogrammetry and calculate RMSE for the operation (Fig. 8) represents the outlines of the methodology workflow of RA-Cop software.

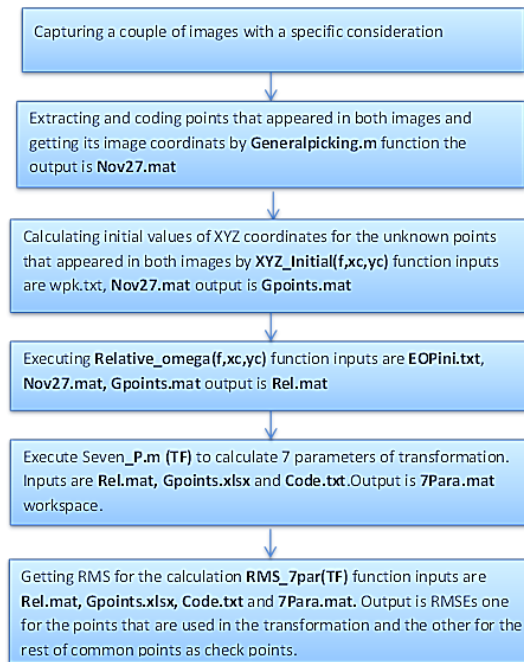


Figure 7: methodology workflow diagram for RA-Col software

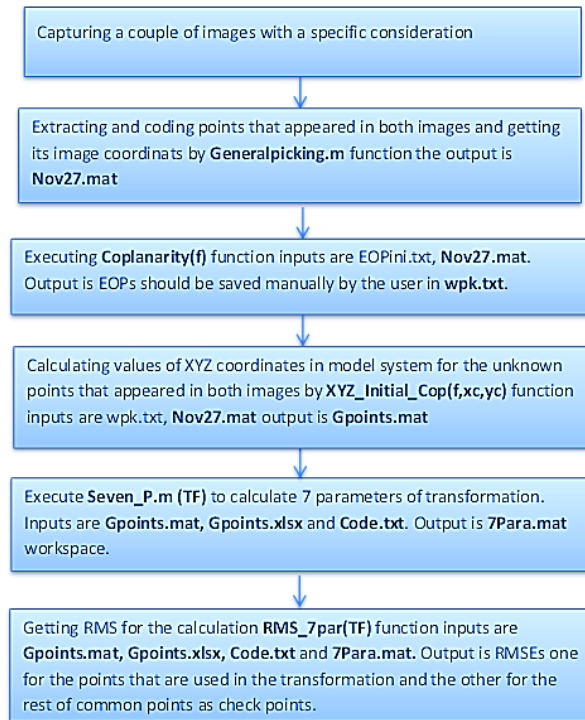


Figure 8: methodology workflow diagram for RA-Cop software

### Mathematical Models

As noted by Ghosh [1], Wolf, DeWitt and Wilkinson [9] and الجبوري، منصور والبكري [10] the mathematical model of collinearity condition is illustrated as below:

$$x - x_c = -f \frac{[m_{11}(X-X_0) + m_{12}(Y-Y_0) + m_{13}(Z-Z_0)]}{[m_{31}(X-X_0) + m_{32}(Y-Y_0) + m_{33}(Z-Z_0)]} = -f \frac{r}{q}$$



$$y - y_c = -f \frac{[m_{21}(X-X_0) + m_{22}(Y-Y_0) + m_{23}(Z-Z_0)]}{[m_{31}(X-X_0) + m_{32}(Y-Y_0) + m_{33}(Z-Z_0)]} = -f \frac{s}{q} \quad \dots (1)$$

Where:

$x, y$  is the image point coordinates.

$X, Y, Z$  is the object point coordinates.

$X_0, Y_0, Z_0$  the coordinates of the exposure station  $O$  in the object space system.

$f$  is the camera principle distance.

$m$  is the elements of rotation matrix.

$x_c, y_c$  is the coordinates of the principal points.

In case of dependent relative orientation the position and the orientation are identical to one of the two image-coordinate systems. This step amounts to introduce the exterior orientation of the image-coordinate system as known that results to eliminate it from the parameter list. Then, defining the scale of the model coordinate system, this is accomplished by defining the distance between the two perspective centers (base) or more precisely by defining the  $X$ -component. Below a functional model [11]

$$x, y = f(y_m'', z_m'', \omega'', \phi'', \kappa'', xm_1, ym_1, zm_1, \dots, xm_n, ym_n, zm_n) \dots (2)$$

EOP of second  
Imagery system

Points of  
1<sup>st</sup> model

Points of  
 $n^{\text{th}}$  model

Where:  $f$  refers to (1).

Every point measured in one image coordinate system renders two equations. The same point must also be measured in the second image coordinate system. Thus, for one model point we obtain 4 equations. With 5 points we obtain 20 observation equations. On the other hand, there are 5 exterior orientation parameters and  $5 \times 3$  model coordinates. Usually more than 5 points are measured. With a nonlinear mathematical model there is a need to start with suitable approximations to ensure that the iterative least squares solution converges. The dependent relative orientation leaves one of the photographs unchanged; the other one is oriented with respect to the unchanged system [11].

The mathematical model of coplanarity condition when relative orientation is achieved is illustrated as below:

Vector  $\vec{R}_{1i}$  from ( $O_1$  to  $P_i$ ) will have an intersection with the vector  $\vec{R}_{2i}$  from ( $O_2$  to  $P_i$ ), and these two vectors together with the air-base vector  $\vec{b}$  will be coplanar. This means that their scalar triple product is zero. The function (mathematical model)  $F_i$  is [1]

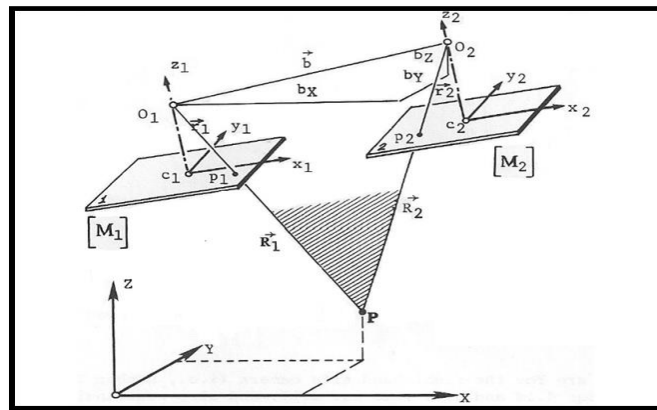


Figure 9: coplanarity condition and relative orientation [1]

$$F_i = \vec{b} \cdot (\vec{R}_{1i} \times \vec{R}_{2i}) = 0 \quad (3)$$

Where:

$F_i$  is the mathematical model.

Furthermore,

$$\vec{b} = \begin{bmatrix} b_x \\ b_y \\ b_z \end{bmatrix} = \begin{bmatrix} X_{O2} & - & X_{O1} \\ Y_{O2} & - & Y_{O1} \\ Z_{O2} & - & Z_{O1} \end{bmatrix} \dots (4)$$

$$\vec{R}_{1i} = \begin{bmatrix} X_{1i} \\ Y_{1i} \\ Z_{1i} \end{bmatrix} = k_1 M_1^T \begin{bmatrix} x_{1i} & - & x_{c1} \\ y_{1i} & - & y_{c1} \\ -f \end{bmatrix} = k_1 M_1^T \vec{r}_{1i}$$

$$\vec{R}_{2i} = \begin{bmatrix} X_{2i} \\ Y_{2i} \\ Z_{2i} \end{bmatrix} = k_2 M_2^T \begin{bmatrix} x_{2i} & - & x_{c2} \\ y_{2i} & - & y_{c2} \\ -f \end{bmatrix} = k_2 M_2^T \vec{r}_{2i}$$

Where:

$i=1$ : n numbers of object points that appeared in both images.

$k_1$  and  $k_2$  are the scale factors of the corresponding location vectors  $\vec{r}_1$  and  $\vec{r}_2$  within the camera space.

$M_1$  and  $M_2$  are the orientation matrices for images 1 and 2, respectively.

$$M^T = \begin{bmatrix} m_{11} & m_{21} & m_{31} \\ m_{12} & m_{22} & m_{32} \\ m_{13} & m_{23} & m_{33} \end{bmatrix}$$

$$= \begin{bmatrix} \cos \varphi \cos \kappa & -\cos \varphi \sin \kappa & \sin \varphi \\ \cos \omega \sin \kappa + \sin \omega \sin \varphi \cos \kappa & \cos \omega \cos \kappa - \sin \omega \sin \varphi \sin \kappa & -\sin \omega \cos \varphi \\ \sin \omega \sin \kappa - \cos \omega \sin \varphi \cos \kappa & \sin \omega \cos \kappa + \cos \omega \sin \varphi \sin \kappa & \cos \omega \cos \varphi \end{bmatrix}$$

The assumptions made about the rotation matrix M are:

- The rotations are in right handed system
- The rotations, proceedings from the ground (or model) coordinates system to the image coordinates system are  $\omega$  primary,  $\varphi$  secondary and  $\kappa$  tertiary [1]

$F_i$  may be written in determinant form as,

$$F_i = \begin{vmatrix} b_x & b_y & b_z \\ X_{1i} & Y_{1i} & Z_{1i} \\ X_{2i} & Y_{2i} & Z_{2i} \end{vmatrix} = 0 \quad \dots (5)$$

Considering a dependent method of relative orientation and assuming equal scale factors for all points in the two images:

Let  $k_1 = k_2 = 1$  and  $x_c = y_c = 0$  moreover the orientation of the first camera station is fixed which represented by  $\omega_1, \varphi_1$  and  $\kappa_1$  while its position represented by  $X_{O1}, Y_{O1}$  and  $Z_{O1}$  are set to zero.

On the other hand the orientation of the second camera station is unknown which represented by  $\omega_2, \varphi_2$  and  $\kappa_2$  while its position represented by  $X_{O2}$  is set to air base B while  $Y_{O2}$  and  $Z_{O2}$  are unknown. The vectors  $\vec{R}_{1i}$  and  $\vec{R}_{2i}$  are then reduced to:

$$\vec{R}_{1i} = \begin{bmatrix} X_{1i} \\ Y_{1i} \\ Z_{1i} \end{bmatrix} = M_1^T \begin{bmatrix} x_{1i} \\ y_{1i} \\ -f \end{bmatrix} \quad \dots (6)$$

$$= \begin{bmatrix} x_{1i} \cos \varphi_1 \cos \kappa_1 & -y_{1i} \cos \varphi_1 \sin \kappa_1 & -f \sin \varphi_1 \\ x_{1i} (\cos \omega_1 \sin \kappa_1 + \sin \omega_1 \sin \varphi_1 \cos \kappa_1) & +y_{1i} (\cos \omega_1 \cos \kappa_1 - \sin \omega_1 \sin \varphi_1 \sin \kappa_1) & +f \sin \omega_1 \cos \varphi_1 \\ x_{1i} (\sin \omega_1 \sin \kappa_1 - \cos \omega_1 \sin \varphi_1 \cos \kappa_1) & +y_{1i} (\sin \omega_1 \cos \kappa_1 + \cos \omega_1 \sin \varphi_1 \sin \kappa_1) & -f \cos \omega_1 \cos \varphi_1 \end{bmatrix} \quad \dots [1]$$



$$\vec{R}_{2i} = \begin{bmatrix} X_{2i} \\ Y_{2i} \\ Z_{2i} \end{bmatrix} = M_2^T \begin{bmatrix} x_{2i} \\ y_{2i} \\ -f \end{bmatrix} \quad \dots (7)$$

$$= \begin{bmatrix} x_{2i} \cos \varphi_2 \cos \kappa_2 & -y_{2i} \cos \varphi_2 \sin \kappa_2 & -f \sin \varphi_2 \\ x_{2i} (\cos \omega_2 \sin \kappa_2 + \sin \omega_2 \sin \varphi_2 \cos \kappa_2) & +y_{2i} (\cos \omega_2 \cos \kappa_2 - \sin \omega_2 \sin \varphi_2 \sin \kappa_2) & +f \sin \omega_2 \cos \varphi_2 \\ x_{2i} (\sin \omega_2 \sin \kappa_2 - \cos \omega_2 \sin \varphi_2 \cos \kappa_2) & +y_{2i} (\sin \omega_2 \cos \kappa_2 + \cos \omega_2 \sin \varphi_2 \sin \kappa_2) & -f \cos \omega_2 \cos \varphi_2 \end{bmatrix} \dots [1]$$

One coplanarity condition equation may be written for each object point. However, it has the main advantage that the coordinates of the points in the object space may be avoided in its applications while the intersection of five pairs of rays  $\vec{R}_1$  and  $\vec{R}_2$  is the requirement of relative orientation [1]. Like collinearity condition equations, they are both non-linear and need to be linearized.

Moreover absolute orientation is the process of orienting a stereo model to the ground control system. This is actually a very straight forward task represented by 7 parameters transformation. The transformation can only be solved if a prior information about some of the parameters is introduced that is mostly done by control points. Vector equation which relates the model to the ground control coordinate system can be explained:

$$X = s M^T x + t \dots (8)$$

Where:

$X$ = the vector  $[X, Y, Z]^T$  in the ground control system pointing to the object point.

$s$ = scale factor.

$M^T$ = the transpose of the rotation matrix  $M$  which rotates vector  $x$  into the ground control system.

$x$ = the point vector  $[x_m, y_m, z_m]^T$  in the model coordinate system.

$t$ = the translation vector or shift vector  $[Tx, Ty, Tz]^T$  between the origins of the two coordinate systems

### The Sensor Size and Image coordinates

It's represented by the dimensions of sensor in millimeters. The transformation from pixel to metric coordinate system is done by using sensor size as illustrated below:

$$x = - (x_{image} - x_c) s_x \dots (9)$$

$$y = - (y_{image} - y_c) s_y \dots (10)$$

Where:-

$(x, y)$  : are the image coordinate expressed in metric units.

$(x_{image}, y_{image})$  : are an arbitrary image point in pixel units.

$(x_c, y_c)$  : are the principal points in pixel units.

$(s_x, s_y)$  : are the effective pixel size in the horizontal and vertical directions respectively (typically expressed in millimeters).

### Results Analysis

This section will focus on processing the previous pair of images by relative and absolute orientation in both types and compute RMSE for each type in order to specify the one that gives more precise results in reconstruction of 3D models. That's will be accomplished by imagery data of the twelve common points of both images. Data processing will be done by using four of the common points as control points and the rest eight ones as check points. As shown in the tables below:

**Table 1: relative orientation method (collinearity)**

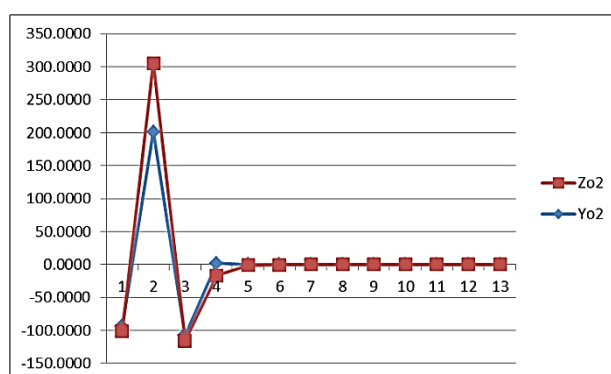
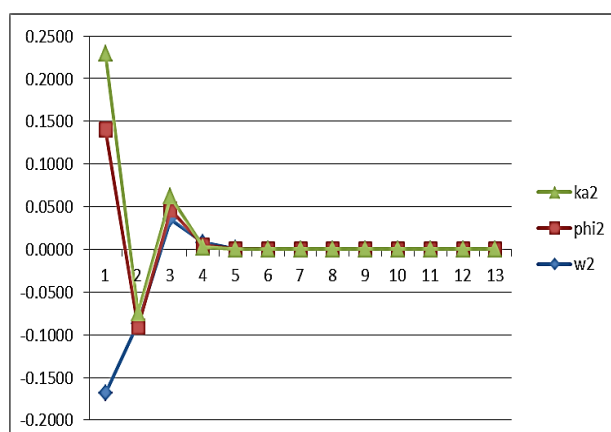
Photogrammetric Method Relative Orientation with Collinearity condition					
Initial values of EOPs					
Left image					
$\omega$ deg	$\phi$ deg	$\kappa$ deg	$X_o$ mm	$Y_o$ mm	$Z_o$ mm
-10	-19	0	0	0	0
Right image					
$\omega$ deg	$\phi$ deg	$\kappa$ deg	$X_o$ mm	$Y_o$ mm	$Z_o$ mm
0	0	0	1400	0	0
Adjusted values of EOPs: 1 <sup>st</sup> trial					
Left image					
orientation and position of the left image are always fixed and wont be adjusted with relative orientation method					
Right image					
$\omega$ dms	$\phi$ dms	$\kappa$ dms	$X_o$ mm	$Y_o$ mm	$Z_o$ mm
-12°07'07.923"	17°58'13.743"	6°47'21.910"		1.913	67.511
Initial values for coordinates of the unknown model points			Adjusted values for coordinates of the unknown model points		
X mm	Y mm	Z mm	X mm	Y mm	Z mm
1: X=1107.408	Y=3039.142	Z=-324.605	1: X=631.670	Y=1992.646	Z=-401.156
2: X=1108.705	Y=3058.307	Z=-253.527	2: X=628.949	Y=1992.883	Z=-350.670
*3: X=1134.854	Y=3081.022	Z=-251.092	*3: X=644.756	Y=2007.445	Z=-349.274
*4: X=1135.839	Y=3092.816	Z=-206.469	*4: X=643.114	Y=2008.674	Z=-318.247
5: X=1154.641	Y=3113.75	Z=-203.482	5: X=653.965	Y=2017.969	Z=-316.123
6: X=1153.673	Y=3108.675	Z=-175.742	6: X=652.951	Y=2018.060	Z=-297.379
7: X=1373.393	Y=3107.333	Z=-174.821	7: X=803.152	Y=2014.276	Z=-288.324
8: X=1372.560	Y=3101.827	Z=-204.472	8: X=804.275	Y=2014.242	Z=-308.557
*9: X=1384.860	Y=3084.874	Z=-206.215	*9: X=814.541	Y=2003.883	Z=-308.361
10: X=1383.313	Y=3074.324	Z=-251.645	10: X=816.395	Y=2003.218	Z=-339.577
*11: X=1399.890	Y=3048.829	Z=-253.631	*11: X=830.601	Y=1988.041	Z=-338.994
12: X=1398.078	Y=3035.164	Z=-327.95	12: X=833.819	Y=1987.979	Z=-390.666
Note: Points with * will be used as known points in 7-parameters transformation					

**Table 2: absolute orientation method (collinearity)**

Absolute Orientation- after relative orientation with collinearity						
Initial values of the 7 Parameters						
$\omega$ deg	$\phi$ deg	$\kappa$ deg	$T_x$ mm	$T_y$ mm	$T_z$ mm	Scale
0	0	0	0	0	0	0.9593
coordinates of the points in model system			coordinates of the same points in ground or object system			
X mm	Y mm	Z mm	X mm	Y mm	Z mm	
*3: X=644.756	Y=2007.445	Z=-349.274	*3: X=100.000	Y=100.000	Z=100.000	
*4: X=643.114	Y=2008.674	Z=-318.247	*4: X=100.000	X=100.000	Z=129.830	
*9: X=814.541	Y=2003.883	Z=-308.361	*9: X=265.060	Y=100.000	Z=129.820	
*11: X=830.601	Y=1988.041	Z=-338.994	*11: X=280.070	Y=85.010	Z=100.000	
Adjusted values of the 7 parameters						
$\omega$ dms	$\phi$ dms	$\kappa$ dms	$T_x$ mm	$T_y$ mm	$T_z$ mm	Scale
0°42'04.393"	3°09'45.193"	1°23'19.988"	-454.495	-1852.584	443.561	0.9631

**Table 3: relative & absolute orientation method RMSE (collinearity)**

Relative and Absolute Orientation with Collinearity Condition					
Coordinates of the actual ground or object points			Coordinates of the calculated ground or object points		
X mm	Y mm	Z mm	X mm	Y mm	Z mm
1: X=85.010	Y=85.000	Z=49.850	1: X=84.996	Y=85.653	Z=50.505
2: X=85.010	Y=85.000	Z=100.000	2: X=85.057	Y=85.221	Z=99.197
*3: X=100.000	Y=100.000	Z=100.000	*3: X=99.988	Y=99.603	Z=99.894
*4: X=100.000	X=100.000	Z=129.830	*4: X=100.029	Y=100.381	Z=129.83
5: X=109.990	Y=110.000	Z=129.830	5: X=110.357	Y=109.565	Z=131.422
6: X=109.990	Y=110.000	Z=149.850	6: X=110.376	Y=109.408	Z=149.500
7: X=255.000	Y=110.000	Z=149.780	7: X=255.340	Y=109.262	Z=150.222
8: X=255.000	Y=110.000	Z=129.820	8: X=255.345	Y=109.494	Z=130.707
*9: X=265.060	Y=100.000	Z=129.820	*9: X=265.466	Y=99.766	Z=130.218
10: X=265.060	Y=100.000	Z=100.000	10: X=265.605	Y=99.537	Z=100.096
*11: X=280.070	Y=85.010	Z=100.000	*11: X=279.647	Y=85.260	Z=99.707
12: X=280.070	Y=85.010	Z=49.850	12: X=279.996	Y=85.886	Z=49.851
			RMSE <sub>x</sub> *=0.2934	RMSE <sub>y</sub> *=0.3242	RMSE <sub>z</sub> *= 0.2527
			TotalRMSE*= 0.5050		
			RMSE <sub>x</sub> = 0.3201	RMSE <sub>y</sub> = 0.5912	RMSE <sub>z</sub> =0.7685
			TotalRMSE= 1.0212		

**Figure 10: corrections and number of iteration of rotation angles****Figure 11: corrections and number of iteration of camera pose**

**Table 4: relative orientation method (coplanarity)**

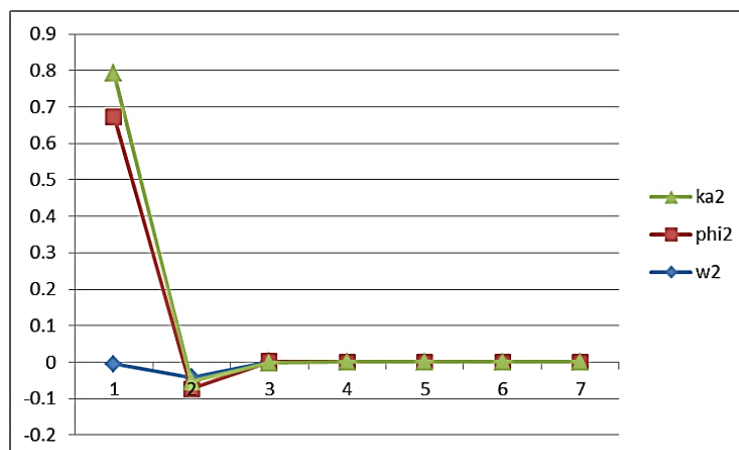
Photogrammetric Method Relative Orientation with Coplanarity condition					
Initial values of EOPs					
Left image					
$\omega$ deg	$\phi$ deg	$\kappa$ deg	$X_o$ mm	$Y_o$ mm	$Z_o$ mm
0	0	0	0	0	0
Right image					
$\omega$ deg	$\phi$ deg	$\kappa$ deg	$X_o$ mm	$Y_o$ mm	$Z_o$ mm
0	0	0	1400	0	0
Adjusted values of EOPs: 1 <sup>st</sup> trial					
Left image					
orientation and position of the left image are allways fixed and wont be adjusted with relative orientation method					
Right image					
$\omega$ dms	$\phi$ dms	$\kappa$ dms	$X_o$ mm	$Y_o$ mm	$Z_o$ mm
-2°29'58.208"	37°01'26.505"	7°38'51.381"		69.591	-471.626
The values of EOPs that are used to find coordinates of the unknown model points					
Left image					
$\omega$ deg	$\phi$ deg	$\kappa$ deg	$X_o$ mm	$Y_o$ mm	$Z_o$ mm
0	0	0	0	0	0
Right image					
$\omega$ dms	$\phi$ dms	$\kappa$ dms	$X_o$ mm	$Y_o$ mm	$Z_o$ mm
-2°29'58.208"	37°01'26.505"	7°38'51.381"	1400	69.591	-471.626
Values for coordinates of the unknown model points					
$X$ mm	$Y$ mm	$Z$ mm			
1: X=-67.734	Y=-51.655	Z=-2240.226			
2: X=-67.517	Y=0.748	Z=-2230.797			
*3: X=-56.610	Y=4.867	Z=-2250.248			
*4: X=-56.813	Y=37.276	Z=-2245.524			
5: X=-49.018	Y=41.168	Z=-2257.988			
6: X=-48.943	Y=60.655	Z=-2254.486			
7: X=102.459	Y=69.345	Z=-2300.861			
8: X=102.384	Y=48.348	Z=-2304.710			
*9: X=116.119	Y=46.659	Z=-2298.064			
10: X=116.331	Y=14.149	Z=-2303.443			
*11: X=135.642	Y=11.978	Z=-2293.368			
12: X=135.790	Y=-41.633	Z=-2303.340			
Note: Points with * will be used as known points in 7-parameters transformation					

**Table 5: absolute orientation method (coplanarity)**

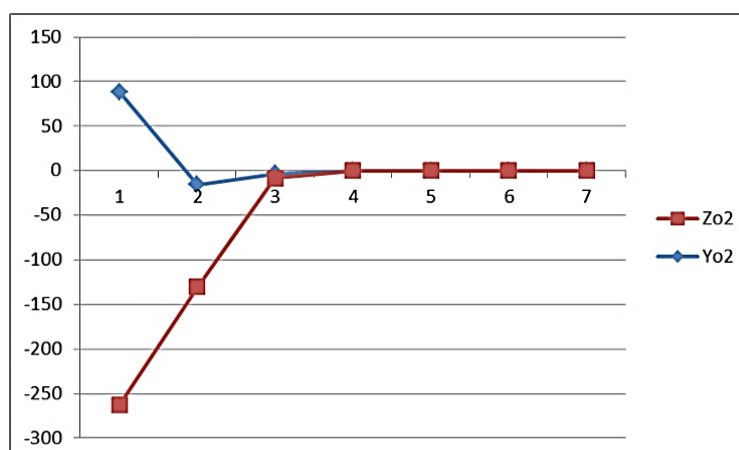
Absolute Orientation- after relative orientation with coplanarity						
Initial values of the 7 Parameters						
$\omega$ deg	$\phi$ deg	$\kappa$ deg	$T_x$ mm	$T_y$ mm	$T_z$ mm	Scale
0	0	0	0	0	0	0.9108
coordinates of the points in model system			coordinates of the same points in ground or object system			
$X$ mm	$Y$ mm	$Z$ mm	$X$ mm	$Y$ mm	$Z$ mm	
*3: X=-56.610	Y=4.867	Z=-2250.248	*3: X=100.000	Y=100.000	Z=100.000	
*4: X=-56.813	Y=37.276	Z=-2245.524	*4: X=100.000	Y=100.000	Z=129.830	
*9: X=116.119	Y=46.659	Z=-2298.064	*9: X=265.060	Y=100.000	Z=129.820	
*11: X=135.642	Y=11.978	Z=-2293.368	*11: X=280.070	Y=85.010	Z=100.000	
Adjusted values of the 7 parameters						
$\omega$ dms	$\phi$ dms	$\kappa$ dms	$T_x$ mm	$T_y$ mm	$T_z$ mm	Scale
79°47'23.818"	-17°06'48.622"	-3°00'25.522"	-456.162	-1851.405	444.019	0.91414

**Table 6: relative& absolute orientation method RMSE (coplanarity)**

Relative and Absolute Orientation with Coplanarity Condition					
Coordinates of the actual ground or object points			Coordinates of the calculated ground or object points		
X mm	Y mm	Z mm	X mm	Y mm	Z mm
1: X=85.010	Y=85.000	Z=49.850	1: X=84.998	Y=85.656	Z=50.523
2: X=85.010	Y=85.000	Z=100.000	2: X=85.052	Y=85.241	Z=99.195
*3: X=100.000	Y=100.000	Z=100.000	*3: X=99.989	Y=99.599	Z=99.898
*4: X=100.000	X=100.000	Z=129.830	*4: X=100.027	Y=100.386	Z=129.827
5: X=109.990	Y=110.000	Z=129.830	5: X=110.359	Y=109.552	Z=131.407
6: X=109.990	Y=110.000	Z=149.850	6: X=110.375	Y=109.403	Z=149.506
7: X=255.000	Y=110.000	Z=149.780	7: X=255.341	Y=109.249	Z=150.216
8: X=255.000	Y=110.000	Z=129.820	8: X=255.349	Y=109.473	Z=130.704
*9: X=265.060	Y=100.000	Z=129.820	*9: X=265.467	Y=99.761	Z=130.217
10: X=265.060	Y=100.000	Z=100.000	10: X=265.609	Y=99.518	Z=100.095
*11: X=280.070	Y=85.010	Z=100.000	*11: X=279.648	Y=85.265	Z=99.708
12: X=280.070	Y=85.010	Z=49.850	12: X=280.002	Y=85.869	Z=49.864
			RMSE <sub>x</sub> *=0.2935	RMSE <sub>y</sub> *=0.3288	RMSE <sub>z</sub> *= 0.2517
			TotalRMSE*= 0.5076		
			RMSE <sub>x</sub> = 0.3221	RMSE <sub>y</sub> = 0.5980	RMSE <sub>z</sub> =0.7653
			TotalRMSE= 1.0230		



**Figure 12: corrections and number of iteration of rotation angles**



**Figure 13: corrections and number of iteration of camera pose**

## Discussion and Conclusions

This paper presents an assessment for data processing using mathematical models of analytical relative and absolute orientation approach by using two methods collinearity method and coplanarity method. As shown in previous tables (1) and (4). These notes are recognized:

- Respecting data processing with relative and absolute orientation with collinearity condition method, it would be operative in case of the presence of approximate values (Rotation angles were estimated from imaging situation) due to correlation between EOPs and points of model system.
- Concerning data processing with relative and absolute orientation with coplanarity condition method, there is no restrictions with initial values because the mathematical model was stable and converged to a solution even with zero for each initial value except the baseline

Based on the analysis of the results that's illustrated in tables (3) and (6) these items are remarked:

- In general the RMSE for both relative and absolute orientation with collinearity and coplanarity methods is nearly identical.

Based on the analysis of the results that's illustrated in figures (10) and (11) for collinearity method, figures (12) and (13) for coplanarity method this items is recognized:

- For collinearity approach the model converged to a final solution after thirteen iterations due to the presence of points in model system within the mathematical model. Also it started to converge after the fourth iteration.
- For coplanarity approach the model converged to a final solution after seven iterations due to the absence of points in model system within the mathematical model. Also it started to converge after the third iteration.

As a final result since 3D modeling and 3D vision are the subjects of the time, it's recommended that using relative and absolute orientation with coplanarity approach in data processing because it's easy to use without restrictions. Moreover it's recommended that in job camera calibration is implemented using the portable control system (PCS) that had been established within this study in order to model the systematic errors that presented in the imagery data and remove its influence on the precision of data processing.

## REFERENCES

- [1] GHOSH, K. S. (2005) *Fundamentals of Computational Photogrammetry*. [online] New Delhi India: Ashok Kumar Mittal. Available from: <http://books.google.iq/books>.
- [2] BARAZZETTI, L. and SCAIONI, M. (2010) Orientation and 3D Modeling from Markless Terrestrial Images Combining Accuracy with Automation. Wiley Online Library. [Online] 25 (132) p.1. Available from: <http://www.onlinelibrary.Wiley.com>.
- [3] AL-JOBOORI, SA. B. and JABER, S. H. (2010) The Feasibility of Close Range Photogrammetry in Three Dimensional Modeling. [Online]. Available from: <http://www.a.academia-assets.com>.
- [4] ALJANABI, J. A. (2012) Establishment of 3D Model with Digital Non-Metric Camera in Close Range Photogrammetry. MSc. thesis. Baghdad: University of Technology
- [5] DAI, F. (2009) Applied Photogrammetry for 3D Modeling, Quantity Surveying and Augmented Reality in Construction. PhD. thesis. Hung Hom, Kowloon, Hong Kong: The Hong Kong Polytechnic University. [Online] Available from: <http://www.lib.polyu.edu.hk>
- [6] AHMAD, A. and RABIU, L. (2011) Generation of Three Dimensional Model of Building Using Photogrammetric Technique. *IEEE 7th International Colloquium on Signal Processing and its Applications*. Penang, 4-6 March 2011. IEEE. pp. 225-231.



- [7]ATYAA, H. and HABIB, A. (2013) Options for Medium Accuracy Architectural Façades Mapping from Terrestrial Photogrammetry. *ASPRS 2013 Annual Conference*. Baltimore, 24 – 28 March 2013.
- [8]ISPRS. (2010) Tips for the Effective Use of Close Range Digital Photogrammetry for the Earth Science. ISPRS - Commission V - Close-Range Sensing: Analysis and Applications Working Group V / 6 - Close range morphological measurement for the earth sciences, 2008-2012.
- [9]WOLF, R. P., DEWITT, A. B. and WILKINSON, E. B. (2000) Elements of Photogrammetry. McGraw- Hill, New York, 3rd edition.
- [10]الجبوري، سليم بشار، منصور، فنار و البكري، ميثم (2009) المسح التصويري التحليلي. كلية الهندسة جامعة بغداد- العراق. إثراء للنشر والتوزيع- الاردن
- [11]SCHENK, T (2005) Introduction to Photogrammetry. Department of Civil and Environmental Engineering and Geodetic Science: The Ohio State University.