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Enhancement of RPC Positioning Accuracy Using Affine Transformation with Different Number of Ground Control Points

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Abstract: The spatial data of satellite image is determined by integration of geometry of imaging sensor and positioning sensors as GPS and star tracking systems. Sensor model is obtained using image geometry and system calibration parameters. Sensor model is not available but Rational Polynomial Function (RPC) model is provided as an alternative representation of sensor model.

RPC model is used in determining spatial data for all features in the captured satellite image. The accuracy of geometric corrected image using RPC model may not be accepted for different applications. The availability of Ground Control Points (GCPs) is a motivation of this research paper in enhancing the accuracy of resultant RPC geometric correction image using GCPs.

The available data is a high resolution satellite image which is captured by IKONOS2 senor. The RPC file with its parameters is available with seven GCPs from ground survey with high accuracy. The RPC model is used to get positioning information of the raw image pixels. The accuracy of the resultant image is tested against available GCPs. Some of available GCPs are added to RPC model with 1st order polynomial mathematical model (affine transformation) in image geometric correction process using ERDAS imagine software. The accuracy for each case of the resultant corrected image using both RPC and GCPs is tested against all the seven available GCPs. The accuracy assessment of the accuracy of resultant image is applied to get not only the improvement quality but also the suitable number of GCPs for enhancing accuracy of RPC geometric correction.

Adding GCPs enhanced the accuracy of RPC geometric correction from around (10.0:20.0) meter accuracy to (1.0:5.0) meter accuracy with 80% improvement factor.

Key Words: Satellite image, RPC, GCPs, Geometric correction

1. Introduction

The satellite imaging system consists of many sensors, image capturing, positioning and navigation systems. They are located in certain positions with respect to each other. The relations between satellite sensors have to be determined by system calibration procedures. The system calibration parameters with the geometry of imaging sensor form physical sensor model as shown in Fig. 1 (a) [1]. Sensor model is not available for many sensors to get the spatial information for each imaging pixel. Rational Polynomial Coefficient (RPC) is used

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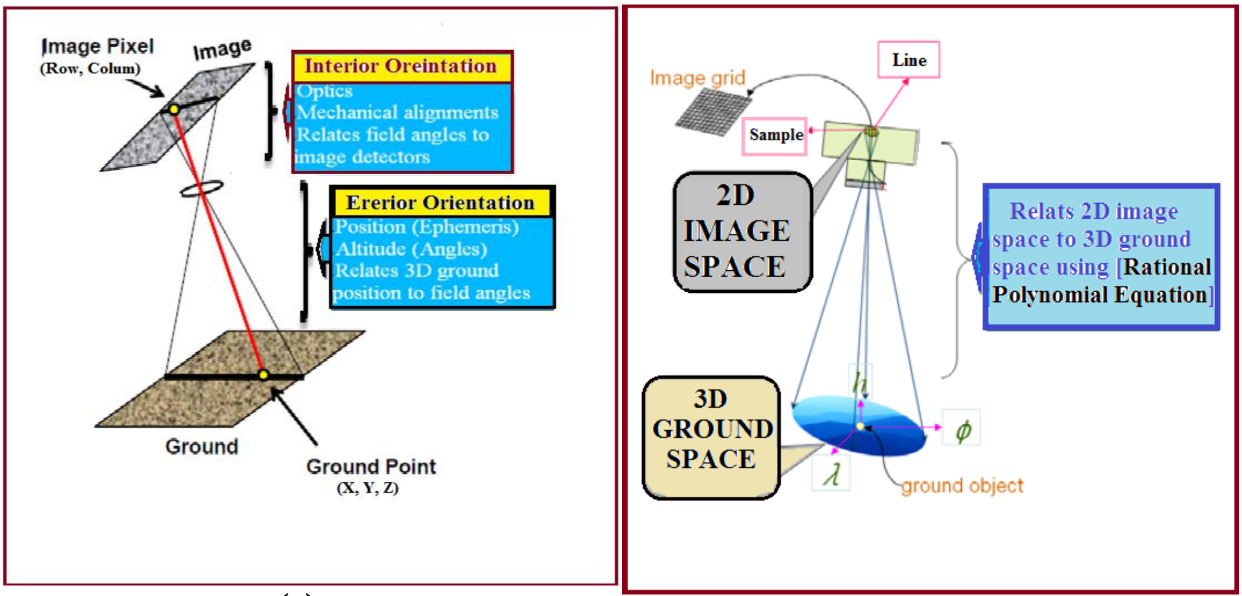
instead of sensor model for geometric correction process and 3D reconstruction of captured images as shown in Fig. 1 (b) [2]. RPC can be provided by the satellite vendors because it is difficult for the users to derive the sensor parameters; As RPC contains many parameters that do not have physical interpretation for the order and terms of these coefficients [2] [3].
RPC is defined as Rational Polynomial Camera coefficient or Rapid Positioning Capability because it is used to transform image pixels from image space to ground space [3]. RPC transform image pixels (l_n, s_n) to ground positions (U, V & w) by using ratio of third order polynomial equations as shown in Equation (1). RPC equations consists of four polynomials $Num_l(U,V,W)$, $Den_l(U,V,W)$,$Num_s(U,V,W)$ and $Den_s(U,V,W)$. Each polynomial contains 20 coefficients as represented in Equation (2), (3), (4) and (5). RPCs comprise 80 coefficients with 10 extra scale and offset terms as shown in Table 1 for IKONOS satellite sensor [4] [5]. RPC is considered as a simpler representation of sensor geometry and calibration parameters instead of lacking of the complicated physical sensor model [1] [6] [7] [3].



(a)

(b)

Fig. 1.
(a): relation between image pixel and corresponding point on the ground using Physical Sensor Model.
(b): relation between image pixel and corresponding point on the ground using Rational Polynomial Coefficient

$$F1 = l_n = \frac{Num_l(U,V,W)}{Den_l(U,V,W)}$$
$$F2 = s_n = \frac{Num_s(U,V,W)}{Den_s(U,V,W)} \qquad \textbf{(1)}$$

Where $(\boldsymbol{l_n}, \boldsymbol{s_n})$ are line and sample in the image coordinates, (*U*, *V*, *W*) are lat., long. And height in the ground coordinates[8] [4].

$$\boldsymbol{Num_l(U,V,W)} = a_1 + a_2V + a_3U + a_4W + a_5VU + a_6VW + a_7UW + a_8V^2 + a_9U^2 + a_{10}W^2 + a_{11}UVW + a_{12}V^3 + a_{13}VU^2 + a_{14}VW^2 + a_{15}V^2U + a_{16}U^3 + a_{17}UW^2 + a_{18}V^2W + a_{19}U^2W + a_{20}W^3 \quad \textbf{(2)}$$

$$\boldsymbol{Den_l(U,V,W)} = b_1 + b_2V + b_3U + b_4W + b_5VU + b_6VW + b_7UW + b_8V^2 + b_9U^2 + b_{10}W^2 + b_{11}UVW + b_{12}V^3 + b_{13}VU^2 + b_{14}VW^2 + b_{15}V^2U + b_{16}U^3 + b_{17}UW^2 + b_{18}V^2W + b_{19}U^2W + b_{20}W^3 \quad \textbf{(3)}$$

$$\boldsymbol{Num_s(U,V,W)} = c_1 + c_2V + c_3U + c_4W + c_5VU + c_6VW + c_7UW + c_8V^2 + c_9U^2 + c_{10}W^2 + c_{11}UVW + c_{12}V^3 + c_{13}VU^2 + c_{14}VW^2 + c_{15}V^2U + c_{16}U^3 + c_{17}UW^2 + c_{18}V^2W + c_{19}U^2W + c_{20}W^3 \quad \textbf{(4)}$$

$$\boldsymbol{Den_s(U,V,W)} = d_1 + d_2V + d_3U + d_4W + d_5VU + d_6VW + d_7UW + d_8V^2 + d_9U^2 + d_{10}W^2 + d_{11}UVW + d_{12}V^3 + d_{13}VU^2 + d_{14}VW^2 + d_{15}V^2U + d_{16}U^3 + d_{17}UW^2 + d_{18}V^2W + d_{19}U^2W + d_{20}W^3 \quad \textbf{(5)}$$

Where:
$(a_0: a_{20})$, $(b_0: b_{20})$, $(c_0: c_{20})$, $(d_0: d_{20})$ are the coefficient of first, second, third and fourth polynomial [4, 5]

2. RPC Refinement Methods

The formation of RPC depends on exterior and interior orientation parameters of the on board satellite imaging and positioning sensors. The orientation parameters of on board sensors contain biases and random errors in common that reflect on the accuracy of the constructed RPC. The accuracy of geometrically corrected images using RPC model may not be accepted for different applications. The RPC model should be refined by integration with data from accurate positioning sensors and/or data from ground surveying process as Ground Control Points (GCPs) [5] [9]. The RPC refinement can be implemented using two methods (direct or indirect) method. Direct refining methods modify the original RPCs by updating the original rational polynomial coefficients themselves, but indirect refining methods do not change the original RPCs directly, it uses a complementary transformation in image space or object space [3] [5] [2].

Indirect refinement methods are most commonly used methods as it doesn't change the original RPC. To implement refinement to RPC model it needs to append a complementary transformation in the image space at the right side of the Equation (1) to eliminate the existing errors. There are many researches use indirect refinement methods with the RPC, such as (Kumar, 2006) the research applied a refinement to the RPC by adding eight GCPs to CARTOSAT –1 stereo data, and errors in the resultant images were reduced from 150 m to 5 m [10]. (Cho et al., 2003) proposed two methods for generation of DEM with IKONOS using modified RPCs with addition of 5 GCPs; The research concluded that this refinement reduced the error by 50% for IKONOS satellite images [9]. (Toutin, 2003) investigated that the accuracy of available GCP affects the number of needed GCPs for refinement process to get required accuracy in case of IKONOS satellite images [11]. (Fraser et al., 2006) uses bias compensated RPC block adjustment method as indirect procedure for RPC refinement in case of both IKONOS and Quick bird images; The accuracy of the resultant corrected image using this method is sub pixel accuracy. This method gave the expected accuracy in case of using camera with narrow angular field of view only with small position and attitude errors [12].

(Zhen Xiong et al., 2009,2013) developed a generic method for RPC refinement using GCP, which has no limitation on camera Field Of View (FOV) or position and attitude errors magnitude and comber it with the bias compensation method, and generic method gives better results [3] [5].

The objective of this research is to investigate the effect of using GCPs on RPC refinement process. The research concentrated on how to effectively improve the geometric accuracy of the RPC sensor model in order to fulfill the user requirement accuracy using minimum number of GCPs. This paper presents a series of experiments using RPC file only then make refinement using different number of GCPs. The complementary geometric correction process using GCPs is applied by 1^{st} order polynomial mathematical model.

3. Area of Study

The area of study is located in Cairo, Egypt with dimension (12*13) km at (2004-02-12 on 08:49 GTM), with bounded coordinates as the upper left corner coordinates are (31° 20′ 36.4727″ E, 30° 10′ 31.7373″ N) and the lower right corner coordinates are (31° 28′ 6.1432″ E, 30° 03′ 11.9254″ N). The input raw image is one scene acquired by remote sensing satellite IKONOS-2 as shown in Fig. 2. The image data contains its RPC file as shown in Table 1. Also, Seven Ground Control Points (GCPs) are available from ground survey for the same area of study with WGS84 datum and Latitude and Longitude projection with accuracy of sub-pixel accuracy as shown in Table 2.

Fig. 2. The input raw image is one scene from IKONOS-2 Satellite

Table 1: Construction of KONOS available RPC file

```
LINE_OFF: +006910.00 pixels
SAMP_OFF: +006195.00 pixels
LAT_OFF: +30.11490000 degrees
LONG_OFF: +031.40650000 degrees
HEIGHT_OFF: +0097.000 meters
LINE_SCALE: +006911.00 pixels
SAMP_SCALE: +006196.00 pixels
LAT_SCALE: +00.06320000 degrees
LONG_SCALE: +000.06540000 degrees
HEIGHT_SCALE: +0270.000 meters

LINE_NUM_COEFF_1: +8.918059928442891E-04
LINE_NUM_COEFF_2: +1.273831558318368E-02
.................................................................   so on till 20
.................................................................
LINE_NUM_COEFF_19: -4.244197945190091E-05
LINE_NUM_COEFF_20: +2.878557422608012E-08

LINE_DEN_COEFF_1: +1.000000000000000E+00
LINE_DEN_COEFF_2: +1.257973104630039E-02
.................................................................   so on till 20
.................................................................
LINE_DEN_COEFF_19: -3.620545095201914E-10
LINE_DEN_COEFF_20: +1.273349786092016E-08

SAMP_NUM_COEFF_1: -1.291292122551020E-03
SAMP_NUM_COEFF_2: +1.017030514352401E+00
.................................................................   so on till 20
.................................................................
SAMP_NUM_COEFF_19: -7.901233399378592E-08
SAMP_NUM_COEFF_20: -1.995044474915829E-07

SAMP_DEN_COEFF_1: +1.000000000000000E+00
SAMP_DEN_COEFF_2: +1.257973104630039E-02
.................................................................   so on till 20
.................................................................
SAMP_DEN_COEFF_19: -3.620545095201914E-10
SAMP_DEN_COEFF_20: +1.273349786092016E-08
```

Table 2: List of Ground Control Points

GCP	E (Longitude)	N (Latitude)	High (m)
GCP # 1	31° 23' 06.19''	30° 08' 39.30''	50.877
GCP # 2	31° 25' 39.63''	30° 08' 18.65''	101.405
GCP # 3	31° 22' 53.24''	30° 07' 43.85''	61.468
GCP # 4	31° 26' 02.24''	30° 07' 52.44''	119.660
GCP # 5	31° 22' 46.90''	30° 06' 36.69''	89.597
GCP # 6	31° 24' 58.42''	30° 06' 58.65''	119.920
GCP # 7	31° 23' 53.42''	30° 05' 59.60''	130.100

4. Methodologies

Since orientation parameters of on board sensors contain biases and random errors in common that affect the accuracy of the constructed RPC, so the results of the original RPC can be post-processed with a polynomial adjustment and several accurate GCPs in order to enhance the positioning accuracy of original RPC. ERDAS IMAGINE software computes the polynomial adjustment math model for each image as shown in Equation (6).

$$line = \Delta p + p(\emptyset, \lambda, h)$$
$$sample = \Delta r + r(\emptyset, \lambda, h)$$

$$\Delta p = A_0 + A_s\,.sample + A_l\,.line + A_{sl}\,.sample.line + A_{s2}\;.\;sample^2 + A_{l2}\,.line^2 + \ldots.. \qquad (6)$$

$$\Delta r = B_0 + B_s\,.sample + B_l\,.line + B_{sl}\,.sample.line + B_{s2}\,.\,sample^2 + B_{l2}\,.line^2 + \ldots\ldots$$

Where
A_0, A_s, A_l, A_{sl} … and B_0, B_s, B_l, B_{sl} … are the are correction coefficients.
$line, sample$ are the line and sample coordinates of an image
Δp , Δr are the adjustable functions expressing the differences between the measured and the nominal line and sample coordinates.

The ERDAS IMAGINE software supports zero, first, second and third order RPC polynomial adjustments. But in general for IKONOS, an affine transformation or a translation for the simplest case is often used as shown in Equation (7) (Grodecki and Dial, 2003; Fraser and Hanley, 2003)

$$\Delta p = A_0 + A_s\,.sample + A_l\,.line$$
$$\Delta r = B_0 + B_s\,.sample + B_l\,.line \quad (7)$$

Where
A_0, A_s, A_l, … and B_0, B_s, B_l, … are correction coefficients.
$line, sample$ are the line and sample coordinates of an image
Δp , Δr are the adjustable functions expressing the differences between the measured and the nominal line and sample coordinates.

The research uses an affine transformation to correct the RPC of IKONOS imagery with different number of GCPs, in order to investigate the required number of GCPs to obtain accuracy of sub pixels.

5. Research Algorithm and Cases of Study

The experimental work is applied using Earth Resources Data Analysis System (ERDAS) Imagine Software version 2013. Input available data are raw IKONOS2 image, with its RPC file and seven GCP from ground survey for the study area as mentioned in the previous section.
Fig. **4** shows the input image containing the distribution of the seven available GCP. The work flow of this research algorithm is shown in Fig. **3**. The input image is corrected firstly by using its RPC file only and check accuracy using the seven available GCPs. Secondly, The refinement of RPC correction process is applied using 1^{st} order polynomial with the RPC mode with different number of GCP in four cases of study; case 1 using 4 GCPs, case 2 using 5 GCPs, case 3 using 6 GCPs and case 4 using 7 GCPs. The used 4GCPs, 5GCPs, 6GCPs and 7GCPs are with specific distribution that gives better results regarding to the previous research [13]. The objective of this research is to investigate the minimum number of GCPs to improve the positioning accuracy of RPC model.

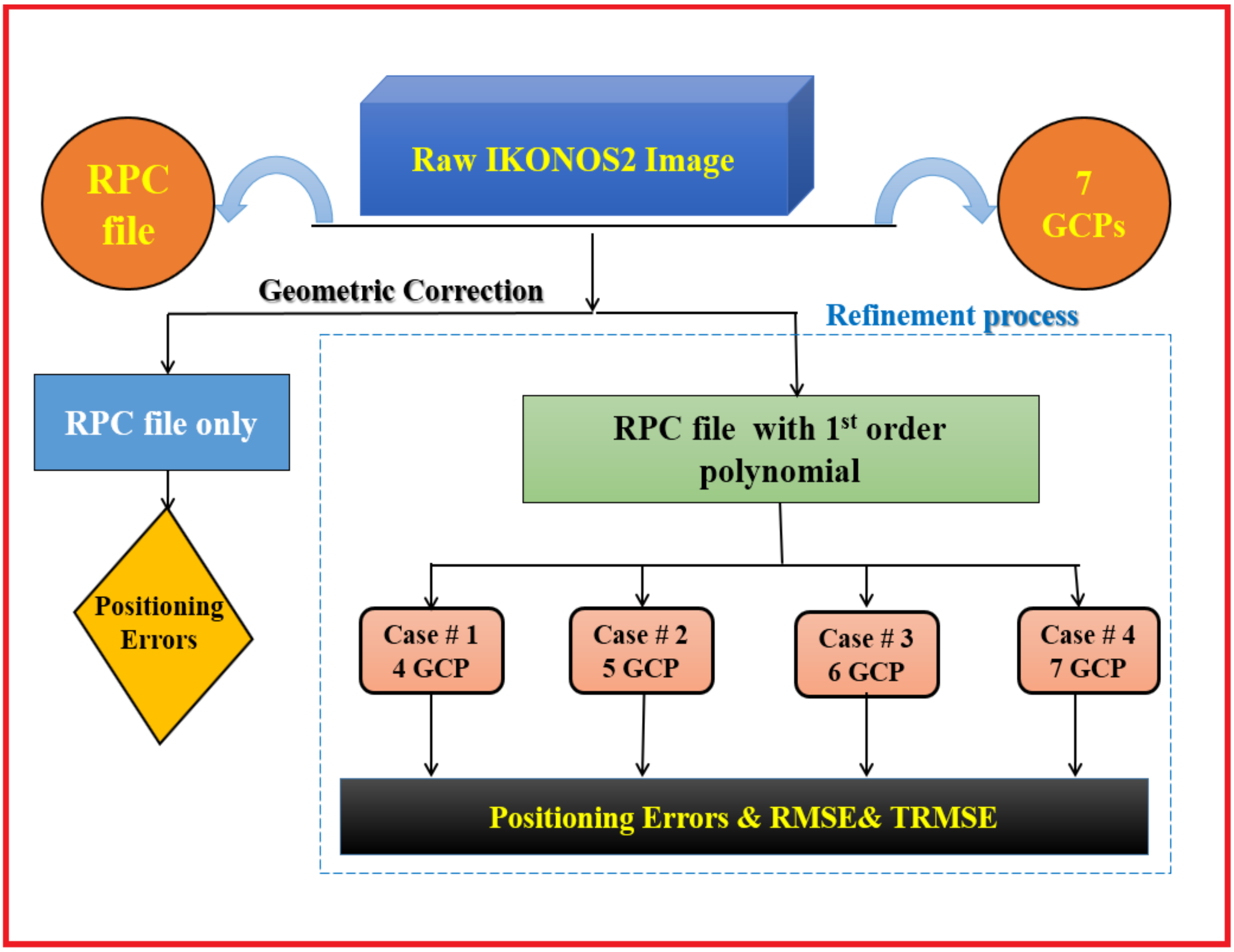


Fig. 3. Work flow of that research

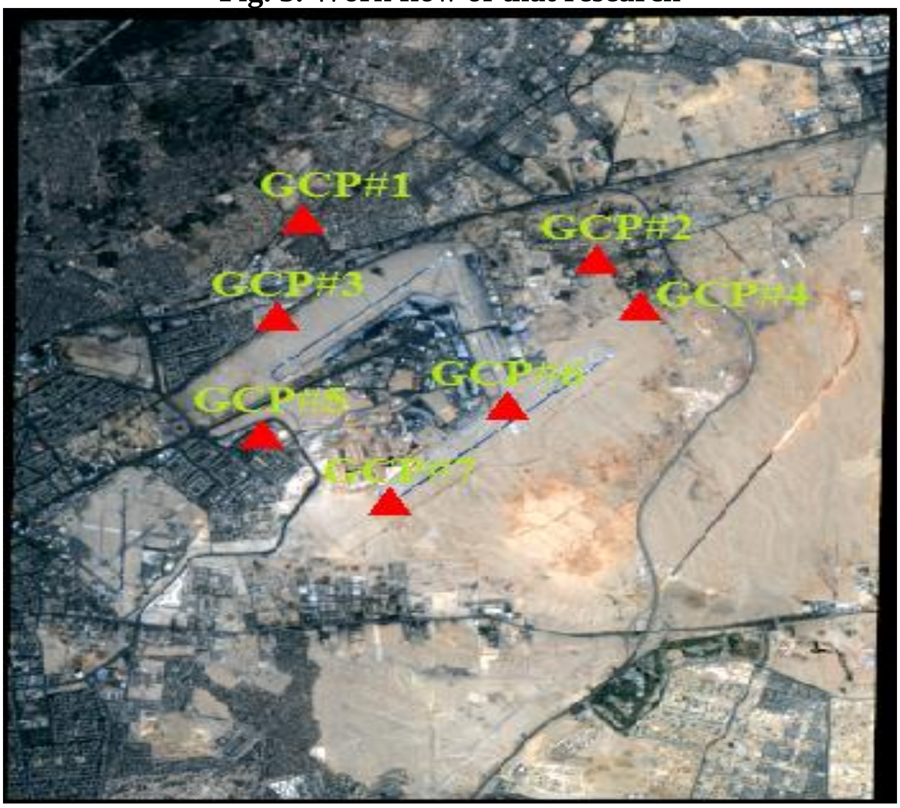


Fig. 4. The distribution of 7 GCP on the input raw image

6. Experimental Results and Assessment

This section shows the results of geometric correction of input image using RPC only and using seven available GCPs to check the accuracy of the resultant image. Then the geometric correction is repeated using RPC with aiding of affine transformation model with different number of existing GCPs and check the accuracy of each case of study using all the seven available GCPs.

6.1 Geometric correction using RPC file only

The Ikonos2 satellite image was rectified using only its RPC file. The positioning accuracy is tested using the seven available GCPs in order to investigate the positioning errors range in each point. Table **3** shows the positing errors in each point of the 7 GCPs for this experiment.

Table 3: Positioning errors in each point of the 7 GCP when using RPC only

Rectification using RPC only					
GCP ID	**GCP Coordinate**		**Measured Coordinate**		**Errors (meter)**
	X reference	X reference	X measured	Y measured	
GCP #1	31° 23\ 06.1907\\	30° 08\ 39.2965\\	31° 23\ 06. 6688\\	30° 08\ 39. 3850\\	13.0741
GCP # 2	31° 25\ 39.6264\\	30° 08\ 18.6540\\	31° 25\ 39. 5150\\	30° 08\ 18. 6322\\	3.0544
GCP #3	31° 22\ 53.2385\\	30° 07\ 43.8527\\	31° 22\ 53. 6357\\	30° 07\ 43. 926\\	10.8620
GCP # 4	31° 26\ 02.3835\\	30° 07\ 52.4428\\	31° 26\ 02. 962\\	30° 07\ 52. 4056\\	11.3311
GCP #5	31° 22\ 46.9019\\	30° 06\ 36.6915\\	31° 22\ 46. 0377\\	30° 06\ 36. 6986\\	3.6392
GCP #6	31° 24\ 58.4185\\	30° 06\ 58.6500\\	31° 24\ 58. 1718\\	30° 06\ 58. 6089\\	6.7200
GCP #7	31° 23\ 53.4226\\	30° 05\ 59.6040\\	31° 23\ 53. 0217\\	30° 05\ 59. 5901\\	10.7336

6.2 Refinement to the RPC using 1st order polynomial

The refinement of geometric correction results using RPC only is applied using GCPs using 1st order polynomial. The refinement results are tested using different number of GCPs forming four cases of study.

6.2.1 Case 1 using four GCP

Four GCPs are used in refinement the geometric correction results of Ikonos2 satellite image when using RPC only. Four points with IDs 1, 2, 3, and 6 are selected in the refinement process and the positioning accuracy in that case is tested using the available 7 GCP from ground survey. Table **4** shows the RMS errors in each point used in case1 and TRMS errors and Table **5** shows the positing errors in each point of the 7 GCP in this case of study.

Table 4: RMS errors in each point in case 1 and TRMSE

Case1 using 4 GCP							
(X) : 0.0099			(Y) : 0.0098			**(TRMSE) : 0.0139**	
GCP ID	**GCP Coordinate**			**Residual**		**Result**	
	X Ref.	Y Ref.	Z Ref.	X	Y	RMSE	Contrib.
GCP #1	31.385	30.144	50.877	-0.011	-0.011	0.016	1.124
GCP # 2	31.428	30.139	101.405	0.007	0.007	0.010	0.712
GCP #3	31.381	30.129	61.468	0.012	0.012	0.017	1.241
GCP # 6	31.416	30.116	119.920	-0.008	-0.008	0.012	0.83

Note: RMSE _ Root Mean Square Error; TRMSE_ Total Root Mean Square Errors; contrib _ contribution

Table 5: Positioning errors in each point of the 7 GCP in meters for case 1

Case 1 using 4 GCP					
GCP ID	GCP Coordinate		Measured Coordinate		Errors (meter)
	X reference	X reference	X measured	Y measured	
GCP #1	31° 23′ 06.1907″	30° 08′ 39.2965″	31° 23′ 06.1513\\	30° 08′ 39.3032″	1.0737
GCP # 2	31° 25′ 39.6264″	30° 08′ 18.6540″	31° 25′ 39. 587\\	30° 08′ 18.6686″	1.1463
GCP #3	31° 22′ 53.2385″	30° 07′ 43.8527″	31° 22′ 53. 273\\	30° 07′ 43.88″	1.2466
GCP # 4	31° 26′ 02.3835″	30° 07′ 52.4428″	31° 26′ 02. 179\\	30° 07′ 52.4355″	5.4551
GCP #5	31° 22′ 46.9019″	30° 06′ 36.6915″	31° 22′ 46. 914\\	30° 06′ 36.6973″	0.3584
GCP #6	31° 24′ 58.4185″	30° 06′ 58.6500″	31° 24′ 58. 393\\	30° 06′ 58.630″	0.9187
GCP #7	31° 23′ 53.4226″	30° 05′ 59.6040″	31° 23′ 53. 272\\	30° 05′ 59.640″	4.1695

6.2.2 Case 2 using five GCP

Five GCPs are used in refinement the geometric correction results of Ikonos2 satellite image when using RPC only. Five points with IDs 1, 3, 4, 5 and 6 are selected in the refinement process and the positioning accuracy in that case is tested using the available 7 GCP from ground survey. Table **6** shows the RMS errors in each point used in case 2 and TRMS errors and Table **7** shows the positing errors in each point of the 7GCP for case 2

Table 6: RMS errors in each point in case 2 and TRMSE

Case 2 using 5 GCP							
(X) : 0.0183			(Y) : 0.0525			**(TRMSE) : 0.0556**	
GCP ID	GCP Coordinate			Residual		Result	
	X Ref.	Y Ref.	Z Ref.	X	Y	RMSE	Contrib.
GCP #1	31.385	30.144	50.877	-0.018	-0.045	0.049	0.876
GCP # 3	31.381	30.129	61.468	0.022	0.090	0.093	1.672
GCP #4	31.434	30.131	119.660	0.017	-0.014	0.022	0.389
GCP #5	31.380	30.110	89.597	0.003	-0.054	0.054	0.973
GCP # 6	31.416	30.116	119.920	-0.023	-0.022	0.032	0.583

Table 7: Positioning errors in each point of the 7 GCP in meters for case 2

Case 2 using 5 GCP					
GCP ID	GCP Coordinate		Measured Coordinate		Errors (meter)
	X reference	X reference	X measured	Y measured	
GCP #1	31° 23′ 06.1907″	30° 08′ 39.2965″	31° 23′ 06. 1623\\	30° 08′ 39. 2900\\	0.7856
GCP # 2	31° 25′ 39.6264″	30° 08′ 18.6540″	31° 25′ 39. 5905\\	30° 08′ 18. 6200\\	1.4237
GCP #3	31° 22′ 53.2385″	30° 07′ 43.8527″	31° 22′ 53. 2878\\	30° 07′ 43. 8500\\	1.3211
GCP # 4	31° 26′ 02.3835″	30° 07′ 52.4428″	31° 26′ 02. 1649\\	30° 07′ 52. 4300\\	5.8596
GCP #5	31° 22′ 46.9019″	30° 06′ 36.6915″	31° 22′ 46. 9289\\	30° 06′ 36. 6700\\	0.9816
GCP #6	31° 24′ 58.4185″	30° 06′ 58.6500″	31° 24′ 58. 3952\\	30° 06′ 58. 6400\\	0.6957
GCP #7	31° 23′ 53.4226″	30° 05′ 59.6040″	31° 23′ 53. 2760\\	30° 05′ 59. 6500\\	4.1719

6.2.3 Case 3 using six GCP

Six GCPs are used in refinement the geometric correction results of Ikonos2 satellite image when using RPC only. Six points with IDs 1, 2, 3, 4, 5 and 6 are selected in the refinement process and the positioning accuracy in that case is tested using the available 7 GCP from ground survey. Table **8** shows the RMS errors in each point used in case 3 and TRMS errors. Table **9** shows the positing errors in each point of the 7GCP for case 3.

Table 8: RMS errors in each point in case 3 and TRMSE

Case 3 Using 6 GCP							
(X) : 0.0447			(Y) : 0.0410			**(TRMSE) : 0.0607**	
GCP ID	GCP Coordinate			Residual		Result	
	X Ref.	Y Ref.	Z Ref.	X	Y	RMSE	Contrib.
GCP #1	31.385	30.144	50.877	0.017	0.009	0.019	0.320
GCP #2	31.428	30.139	101.405	0.060	0.052	0.079	1.310
GCP # 3	31.381	30.129	61.468	-0.060	-0.027	0.066	1.090
GCP #4	31.434	30.131	119.660	-0.057	-0.072	0.092	1.509
GCP #5	31.380	30.110	89.597	0.034	-0.001	0.034	0.559
GCP # 6	31.416	30.116	119.920	0.006	0.038	0.039	0.636

Table 9: Positioning errors in each point of the 7 GCP in meters for case 3

Case 3 Using 6 GCP					
GCP ID	**GCP Coordinate**		**Measured Coordinate**		**Errors (meter)**
	X reference	X reference	X measured	Y measured	
GCP #1	31^o 23\ 06.1907\\	30^o 08\ 39.2965\\	31^o 23\ 06. 1741\\	30^o 08\ 39. 2800\\	0.6763
GCP # 2	31^o 25\ 39.6264\\	30^o 08\ 18.6540\\	31^o 25\ 39. 5937\\	30^o 08\ 18. 6200\\	1.3675
GCP #3	31^o 22\ 53.2385\\	30^o 07\ 43.8527\\	31^o 22\ 53. 2934\\	30^o 07\ 43. 8500\\	1.4706
GCP # 4	31^o 26\ 02.3835\\	30^o 07\ 52.4428\\	31^o 26\ 02. 1689\\	30^o 07\ 52. 4000\\	5.8898
GCP #5	31^o 22\ 46.9019\\	30^o 06\ 36.6915\\	31^o 22\ 46. 9359\\	30^o 06\ 36. 6800\\	0.9765
GCP #6	31^o 24\ 58.4185\\	30^o 06\ 58.6500\\	31^o 24\ 58. 4005\\	30^o 06\ 58. 6400\\	0.5722
GCP #7	31^o 23\ 53.4226\\	30^o 05\ 59.6040\\	31^o 23\ 53. 2826\\	30^o 05\ 59. 6700\\	4.2653

6.2.4 Case 4 using seven GCP

Seven GCPs are used in refinement the geometric correction results of Ikonos2 satellite image when using RPC only. Seven points with IDs 1, 2, 3, 4, 5, 6 and 7 are selected in the refinement process and the positioning accuracy in that case is tested using the available 7 GCP from ground survey. Table **10** shows the RMS errors in each point used in case 4 and TRMS errors. Table **11** shows the positing errors in each point of the 7GCP for case 3.

Table 10: RMS errors in each point in case 4 and TRMSE

Case 4 Using 7 GCP							
(X) : 0.0623			(Y) : 0.0626			**(TRMSE) : 0.0883**	
GCP ID	GCP Coordinate			Residual		Result	
	X Ref.	Y Ref.	Z Ref.	X	Y	RMSE	Contrib.
GCP #1	31.385	30.144	50.877	-0.039	-0.056	0.068	0.771
GCP #2	31.428	30.139	101.405	0.066	0.053	0.085	0.960
GCP # 3	31.381	30.129	61.468	-0.009	0.103	0.103	1.166
GCP #4	31.434	30.131	119.660	0.026	-0.037	0.045	0.510
GCP #5	31.380	30.110	89.597	0.068	-0.076	0.102	1.150
GCP # 6	31.416	30.116	119.920	-0.0126	-0.037	0.131	1.463
GCP #7	31.398	30.100	130.100	0.014	0.050	0.052	0.585

Table 11: Positioning errors in each point of the 7 GCP in meters for case 4

Case 4 Using 7 GCP					
GCP ID	GCP Coordinate		Measured Coordinate		Errors (meter)
	X reference	X reference	X measured	Y measured	
GCP #1	31° 23\ 06.1907\\	30° 08\ 39.2965\\	31° 23\ 06. 1500\\	30° 08\ 39. 3072\\	1.1375
GCP # 2	31° 25\ 39.6264\\	30° 08\ 18.6540\\	31° 25\ 39. 5850\\	30° 08\ 18. 6298\\	1.3363
GCP #3	31° 22\ 53.2385\\	30° 07\ 43.8527\\	31° 22\ 53. 3066\\	30° 07\ 43. 8810\\	2.0206
GCP # 4	31° 26\ 02.3835\\	30° 07\ 52.4428\\	31° 26\ 02. 2314\\	30° 07\ 52. 4405\\	4.0684
GCP #5	31° 22\ 46.9019\\	30° 06\ 36.6915\\	31° 22\ 46. 9441\\	30° 06\ 36. 7063\\	1.2181
GCP #6	31° 24\ 58.4185\\	30° 06\ 58.6500\\	31° 24\ 58. 3908\\	30° 06\ 58. 6428\\	0.7736
GCP #7	31° 23\ 53.4226\\	30° 05\ 59.6040\\	31° 23\ 53. 2647\\	30° 05\ 59. 6487\\	4.4446

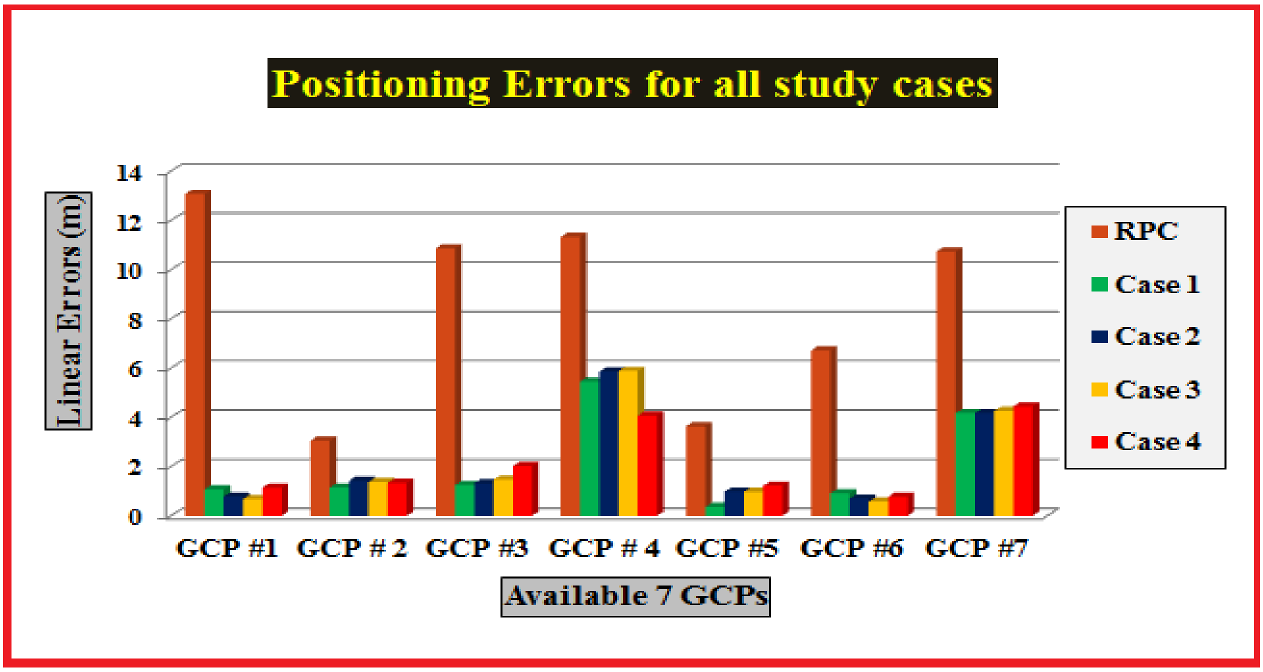


Fig. 5. The distribution of 7 GCP on the input raw image

7. Conclusions

In this paper, briefly illustrates the difference between physical sensor model and rational polynomial coefficient model was presented. The new challenge is the utilized of the RPC functional model which is provided by satellite vendors instead of PM models to be used in photogrammetric processing, correction processes and 3D reconstruction. However, the desired positioning accuracy when using RPC model may not satisfy image users to be used for different applications. For this limitation, many investigators have proposed methods to improve the accuracy of RPC models.

In our research, use Earth Resources Data Analysis System (ERDAS) Imagine Software version 2013. Firstly shows the results of geometric correction of input image using RPC only. Secondly, study the refinement of RPC model with aiding of affine transformation model, with different number of existing GCPs. The accuracy assessment for all cases of study is implemented by using all the seven available GCP using MATLAB function.

The results show that adding GCPs enhanced the accuracy of RPC geometric correction from around (10.0:20.0) meter accuracy to (1.0:5.0) meter accuracy with 80% improvement factor, so refinement of RPC model is important process to extract accurate spatial information from images to de used for different application.

This research investigated that when using affine transformation as a complementary model in order to refine the positioning errors of the original IKONOS RPC file, only four GCPs with sub pixel accuracy are enough with study area same like used in the research as possible. This are concluded by compering firstly, TRMSE that represents the overall error value for all cases of refinement and of all cases case 1 (using 4 GCPs) gives the minimum value (**0.0139**). Also, by compering linear errors in the seven available GCPs for all cases of refinement, its clearly identified that case 1(4GCPs) are sufficient, as it uses minimum number of GCPs that preserve time consuming and saving money.

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