# Determination of suitable requirements for Geometric Correction of remote sensing Satellite Images when Using Ground Control Points

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***Abstract -****Geometric correction is an important process for producing georeferenced remote sensing images that are used for many applications as map production, feature measurements, change detection and object tracking. Geometric correction is a post processing process that is applied on captured remote sensing images for correcting images against sensor and/or environmental error sources. There are different geometric correction techniques depending on an algorithm, a source of distortion and nature of available data.*

*The available data is a satellite image for an area of study without information about its coordinates, projection or source of distortion. Ground Control Points (GCPs) are available for the same area of study. Geometric correction process for image of study area is applied many times based on different number of available GCPs and based on different mathematical model approaches. The objective of this research paper is to get the suitable requirements for geometric correction for satellite images using Ground Control Points (GCPs).*

*The research investigated the optimum requirements for an input satellite image using CGPs. Assessment based on Root Mean Square (RMS) values is used to estimate the accuracy of resultant images. Theminimum and optimum requirements are achieved when using 4 GCPs with specific distribution. The geometric correction gave accurate results when using two dimensional coordinate transformations with first order degree of polynomial with of minimum number of GCPs.*

***Key Words:*** Geometric Correction, Satellite Images, Two Dimensional Transformation, Interpolation, Ground Control Points**.**

## 1.INTRODUCTION

Geometric correction is an important process to get accurate spatial information about features from remote sensing images [1]. Accurate spatial data is necessary in many civil and military applications as city planning, infrastructure projects and object tracking. Remote sensing image has to be free of distortion that may be existed from different sources as inaccurate sensor calibration, effect of earth curvature and/or atmospheric refraction. In addition to these distortions, the deformations related to the map projection have to be taken into account [2].

Geometric correction is a post processing process that is applied on the captured remote sensing images for correcting images against sensor and/or another error sources [3]. Geometric correction is applied on images by using mathematical models of corrections against error sources in case of known sources of errors. Geometric correction of image without any information about the sources of error is a challenge. There are many techniques used for geometric correction based on available spatial data.

Geometric correction is applied to transform image pixels from coordinate system to another coordinate system related to available reference data [1]. Different methods for the transformation of one coordinate system to another as Helmert transformation, affine transformation, projective transformation, and polynomial transformation. Polynomials offer many advantages such as simple form, moderate flexibility of shapes, well-known, understood properties and ease of use computationally, so the research propose using a polynomial model.[4]Polynomial transformation requires the use of reference data with known ground coordinates as ground control points (GCPs) and/or georeferenced image [5].

There are different researches applied geometric correction on remote sensing images that deal with main influencing factors of image rectification accuracy as accuracy of control points, distribution of control points, number of control points and transformation models. Ok and M. Turker (2004) carried out accuracy assessments of the orthorectification of ASTER imagery using twelve different mathematical models (two rigorous and ten simple geometric models) through Matlab version 6.5 environment for ten simple models in order to find the effect of the number of GCPs on the accuracy of orthorectification, The researches ended up with that the second order polynomial with relief model developed in this study can be efficiently used for the orthorectification of the ASTER imagery because of simplicity and consistency [6].

Hosseini et al., (2005) applied non-rigorous mathematical models in two dimensional (2D) and three dimensional

(3D) cases of study for geometric corrections for an IKONOS image in Iran. The results conclude that Multiquadratic with third order polynomial is the best model in 2D case of study and Multiquadratic with Direct Linear Transform (DLT) model is the best model in 3D case of study [7]. Jacobsen (2006) tested the effects of number of GCPs on the accuracy of resultant image in case of using IKONOS images. the researcher announced that 3D projective and 3D affine transformation with fifteen GCPs is required to reach the level of one pixel accuracy [8].

Hamza et al., (2009) applied a third order polynomial using ten GCPs and studied the effect of the selected location of GCPs and the way of distribution of the selected GCPs over the distorted image area on geometric correction accuracy. The results conclude that to obtain high accuracy of geometric correction of remote sensing satellite images, the location and distribution of selected GCPs should be taken into consideration, also the effect of bad location of selected GCPs is more severe than that of bad distribution of selected GCPs on the correction accuracy [9].

Santhosh et al., (2011) applied image to map geo-correction using polynomial transformation using sixteen GCPs through ERDAS Imagine 9.1 software. The result shows the geometric correction process using polynomial model gives a Root Mean Square (RMS) error equals to 0.6 so it is below the one pixel, which will provide the high quality georeferenced image [10].

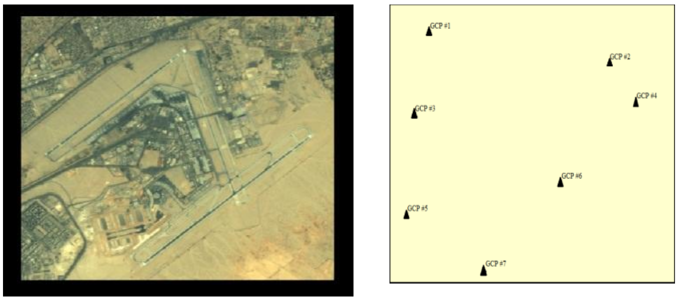
Santhosh et al., (2014) applied a new approach hybrid model, a global polynomial and then applied projectivetransformation, to the calculated coordinates from global polynomial. The results conclude that a hybrid model, global polynomial and then projective transformation, gives the best results compared to results after applying global polynomial alone or applying projective transformation alone especially for high resolution satellite imageries such as IRS-P6 LISS III (IRS-P6 (Indian Remote-Sensing Satellite) & LISS III (Linear Imaging Self-Scanning Sensor-III) with resolution 23.5m) [1].

El Amin et al., (2016) tested different numbers of CGPs with different densifications for geometric correction of aerial image. The researchers investigated that three GCPs with specific distribution and densification are enough for geometrical correction of aerial images [11].

The objective of this research paper is to get the suitable requirements for geometric correction using GCPs for satellite images. The suitable requirements are the optimum number of ground control points with their distribution and the degree of polynomial that is used in transformation process.

## 2. AREA OF STUDY

The area of study is located in Cairo, Egypt with bounded coordinates as the upper left corner coordinates are (31° 22\ 31.6868\\ E, 30° 8\ 43.4312\\ N) and the lower right corner coordinates are (31° 26\ 2.7537\\ E, 30° 5\ 48.1822\\ N). The input image study area is acquired by remote sensing satellite IKONOS. There is no information about its coordinates, projection or source of distortion as shown in Fig -1(a). Seven Ground Control Points (GCPs) are also available from ground survey forthe same area of study with WGS84 datum and Latitude and Longitude projection. The distribution of available CGPs in the raw image as shown in Fig -1(b) and Table - **1** shows the list of their coordinates.



(a) Raw image (b) Distribution of (7) GCPs

**Fig -1:** Raw image and distribution of available GCPs

**Table - 1**: List of Ground Control Points

| GCP | E (Longitude) | N (Latitude) |
|---|---|---|
| **GCP # 1** | 31° 23\ 06.19\\ | 30° 08\ 39.30\\ |
| **GCP # 2** | 31° 25\ 39.63\\ | 30° 08\ 18.65\\ |
| **GCP # 3** | 31° 22\ 53.24\\ | 30° 07\ 43.85\\ |
| **GCP # 4** | 31° 26\ 02.24\\ | 30° 07\ 52.44\\ |
| **GCP # 5** | 31° 22\ 46.90\\ | 30° 06\ 36.69\\ |
| **GCP # 6** | 31° 24\ 58.42\\ | 30° 06\ 58.65\\ |
| **GCP # 7** | 31° 23\ 53.42\\ | 30° 05\ 59.60\\ |

## 3. RESEARCH ALGORITHM

Geometric correction is applied using a number of given GCPs with specific degree of polynomial. The research objective is to determine the suitable number of GCPs with degree of polynomial to get accurate results from available data.

Fig **-2** shows a schematic diagram of algorithm to fulfil the research objective.

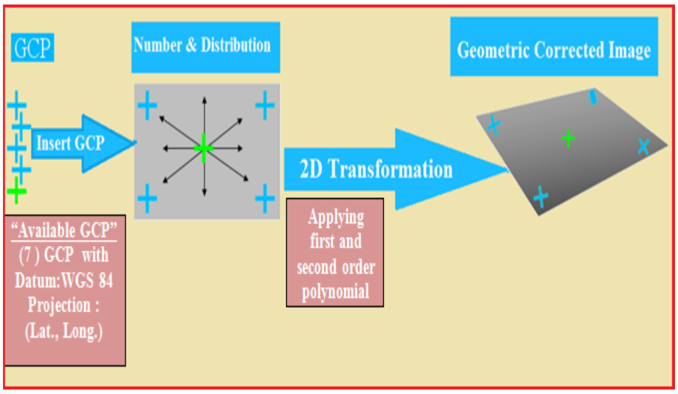



**Fig -2**: A schematic algorithm of work flow of that research

## 4. METHODOLOGIES

The geometric correction of an image using GCPs is applied by executing two dimensional transformation processes. This process is applied to transform the coordinates of image pixels from image coordinate system to ground coordinate system. The transformation represented as functions with observations and unknowns. Observations are the image coordinates of pixels associated to the GCPs and their ground coordinates. Unknowns are the transformation parameters which are translation and rotation parameters. The mathematical representation of the transformation equations are polynomials. The number of transformation parameters depends on the degree of used polynomial. The research is working on investigating the optimum degree of polynomial for geometric correction using available data.

### 4.1 Two-Dimensional Transformation

2D transformation can be used to project image f (u, v) coordinate on to the ground g (x, y) coordinates. The transformation involves scale factors in x and y directions, two translations from the origin and a rotation of x and y axes about the origin[8].

### 4.2 Two-Dimensional Polynomials Transformation

This search had been oriented to get the suitable requirements for geometric correction (rectification) for a two dimensional image using GCPs. The research tested different degrees of polynomials based on available GCPs. The order of transformation is ranged from 1st - through nth-order polynomials.

The mathematical model of first order polynomial that is known as affine transformation equation has six unknowns which needs minimum of 3 GCPs as shown in Equation (1).

$$x = a_0 + a_1 X + a_2 Y$$
$$y = b_0 + b_1 X + b_2 Y \qquad (1)$$

Where:

x, y = image coordinate

X, Y = reference coordinate

$a_0$,$b_0$, $a_1$ , $b_1$ ,$a_2$, $b_2$ = translation, rotation and scaling parameters

The mathematical model of second order polynomial which is known as nonlinear transformation equation is used to correct more complicated types of distortion. The equations of second order polynomial have twelve unknowns which need minimum of 6 GCPs as shown in Equation (2).

$$x = a_0 + a_1 X + a_2 Y + a_3 XY + a_4 X^2 + a_5 Y^2$$
$$y = b_0 + b_1 X + b_2 Y + b_3 XY + b_4 X^2 + b_5 Y^2 \qquad (2)$$

Where:

x, y = image coordinate

X, Y = reference coordinate

$a_0$,$b_0$, $a_1$, $b_1$,$a_2$, $b_2$, $a_3$, $b_3$, $a_4$, $b_4$,$a_5$, $b_5$= translation, rotation and scaling parameters

The minimum number of selected GCPs depends on the order of the polynomial, as three points define a plane. Therefore, to perform a first order transformation, which is expressed by the equation of a plane, at least three GCPs are needed. Similarly, the equation used in a second order transformation is the equation of a paraboloid, at least six points are required [5]. Equation (3) shows the mathematical relation between minimum numbers of required ground control points and a transformation of order t.

$$\text{Min. Number of required GCP} = \frac{((t+1)(t+2))}{2} \qquad (3)$$

Where:

t= is the order of polynomial equation used

The used of minimum number of GCPs tends to get the unknown transformation parameters without capability to check the accuracy of calculated parameters so, it is required to use additional one GCP to the minimum number of GCPs calculated from Equation (3) to apply least square method [5]. The accuracy of overall process that is used to calculated transformation parameters is determined by calculating Total Root Mean Square (TRMS). The Root Mean Square (RMS) error is the distance between the input (source) location of a GCP and the retransformed location for the same GCP. The RMS error of each point used to evaluate the GCPs as shown in

Equation (4) which is expressed in pixel widths. Fig -3 illustrates the relationship between the residuals and the RMS error per point. The X Residual is the distance between the source X coordinate and the retransformed X coordinate and Y Residual is the distance between the source Y coordinate and the retransformed Y coordinate [5]. TheTRMS error is determined by the formula shown in Equation

(5). Error Contribution by Point is normalized values representing each point's RMS error in relation to the total RMS error is determined by the formula in Equation (6).

$$R_i = \sqrt{XR_i^2 + YR_i^2} \quad (4)$$

Where:

$R_i$= the RMS error for $GCP_i$ ; $XR_i$ =the X residual for $GCP_i$ ; $YR_i$ = the Y residual for $GCP_i$

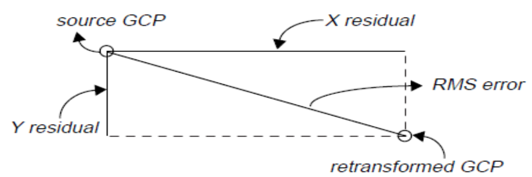



**Fig -3:**Relationship Between Residuals and RMS error per point [5]

$$T = \sqrt{\frac{1}{n}\sum_{i=1}^{n} XR_i^2 + YR_i^2} \quad (5)$$

Where:

T= total RMS error; n= the number of GCPs; i= GCP number; $XR_i$ =the X residual for GCPi ; $YR_i$ = the Y residual for $GCP_i$

$$E_i = \frac{R_i}{T} \quad (6)$$

Where:

$E_i$ = error contribution of $GCP_i$; $R_i$ = the RMS error for $GCP_i$; T = total RMS error.

## 5. GEOMETRIC CORRECTION RESULTS AND ASSESSMENT

The experimental work is applied using Earth Resources Data Analysis System (ERDAS) Imagine Software. The maximum degree of polynomial is the second order since the available GCPs are seven and they are suitable for no more than second order polynomial. So, the research is applied to investigate the suitable number of ground control points with first and second order polynomials.

### 5.1 Results in Case of Using First Order polynomial

Geometric correction needs 4 GCPs as minimum number of control points as calculated from Equation (3).The available GCPs is seven so, the objective of the research is to investigate what are the suitable control points from the available in case of using first order polynomial. The optimum used control points are the minimum number of GCPs with their distribution. The other available GCPs are used in accuracy assessment in all cases of study to detect the case of using optimum GCPs.

Fig -4 illustrates a flow chart of work flow of in case of using first order polynomial showing the cases of study for each group of available GCPs.

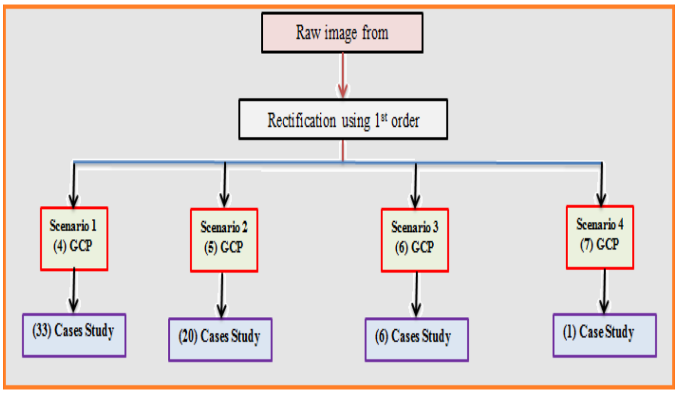



**Fig -4:**A flow chart of work flow in case of using 1st order polynomial

In case of rectification using 1st order polynomial with using GCP, and study this in 4 Scenarios, Scenario (1) using (4 GCP) with (33) cases of study, Scenario (2) using (5 GCP) with (20) cases of study, Scenario (3) using (6 GCP) with (6) cases of study; Scenario (4) using (7 GCP) with (1) case study.

Table 2 shows Total RMS in each case of study in first scenario. **Fig - 5**show the distribution of used GCPs [Green Color] and remaining GCPs which used as Check Points (CPs) [Magenta Color] in the case of study number 10 that gives higher accuracy with minimum Total RMS and **Table 3**(A and B) shows list of used GCPs in this case of study with RMS in X and Y coordinates and list of remaining points which used as check points CP with errors in X and Y coordinate in this case of study respectively.

**Table 2 :** Total RMS error in each case of scenario (1) when applying 1st order polynomial

| Cases of Study | Used GCPs | TRMSE | Cases of Study | Used GCPs | TRMSE |
|---|---|---|---|---|---|
| Case 1 | (1,2,3,4) | 0.2009 | Case 18 | (4,7,1,2) | 0.2817 |
| Case 2 | (1,3,4,5) | 0.2005 | Case 19 | (5,3,7,1) | 0.1817 |
| Case 3 | (1,4,5,6) | 0.1479 | Case 20 | (5,7,1,2) | 0.1425 |
| Case 4 | (1,5,6,7) | 0.28 | Case 21 | (4,5,1,2) | 0.2575 |
| Case 5 | (1,6,7,2) | 0.3379 | Case 22 | (1,3,5,6) | 0.2021 |
| Case 6 | (1,7,2,3) | 0.2415 | Case 23 | (1,4,3,7) | 0.2901 |
| Case 7 | (2,3,4,5) | 0.3102 | Case 24 | (1,2,3,5) | 0.1943 |
| Case 8 | (2,4,5,6) | 0.2077 | Case 25 | (1,2,4,6) | 0.2472 |
| Case 9 | (2,5,6,7) | 0.3528 | Case 26 | (1,4,5,7) | 0.2121 |
| Case 10 | (2,6,3,1) | 0.0251 | Case 27 | (2,3,6,7) | 0.3703 |
| Case 11 | (4,6,1,3) | 0.1461 | Case 28 | (2,3,4,6) | 0.259 |
| Case 12 | (3,4,5,6) | 0.3102 | Case 29 | (2,3,5,6) | 0.2703 |
| Case 13 | (3,5,6,7) | 0.134 | Case 30 | (2,3,4,7) | 0.337 |
| Case 14 | (3,6,7,1) | 0.3361 | Case 31 | (2,4,6,7) | 0.2642 |
| Case 15 | (5,6,1,2) | 0.0479 | Case 32 | (3,4,6,7) | 0.2532 |
| Case 16 | (4,5,6,7) | 0.2528 | Case 33 | (3,4,5,7) | 0.0524 |
| Case 17 | (4,6,7,1) | 0.2564 | | | |


**Fig - 5:**Distribution of used GCPs [Green Color] and Distribution of CPs [Magenta Color] in case study number (10) for the first scenario that gives the best Total RMS error

**Table 3 :**List of Error Result of used GCPs (A) and CPs (B) in case of study number 10 of first scenario

(A)

| **Control point Error: (x) = 0.0204, (y) = 0.0146 TRMS = 0.0251** | | | | |
|---|---|---|---|---|
| **GCP Point ID** | **Residual** | | **Result** | |
| | **X** | **Y** | **Contrib.** | **RMSE** |
| GCP # 1 | 0.023 | -0.016 | 1.124 | 0.028 |
| GCP # 2 | -0.015 | 0.01 | 0.712 | 0.018 |
| CP # 3 | -0.025 | 0.018 | 1.242 | 0.031 |
| GCP # 6 | 0.017 | -0.012 | 0.83 | 0.021 |

(B)

| **Check point Error: (x) = 0.9612, (y) = 0.6419 Total = 1.1559** | | | | |
|---|---|---|---|---|
| **CP Point ID** | **Residual** | | **Result** | |
| | **X** | **Y** | **Contrib.** | **RMSE** |
| CP # 4 | -0.678 | -0.221 | 0.617 | 0.713 |
| CP # 5 | 0.823 | -0.475 | 0.822 | 0.95 |
| CP # 7 | 1.279 | -0.981 | 1.612 | 1.394 |

**Table 4**shows Total RMS in each case of study in second scenario.

Fig **-6** show the distribution of used GCPs [Green Color] and remaining GCPs which used as CPs [Red Color] in the case (7) that gives higher accuracy with minimum Total RMS and **Table 5**(A and B) shows list of used GCPs in this case of study with RMS in X and Y coordinates and list of remaining points which used as check points with errors in X and Y coordinate in this case of study respectively.

**Table 4 :** Total RMS error in each case of scenario (2) when applying 1st order polynomial

| Cases of Study | Used GCPs | TRMS E | Cases of Study | Used GCPs | TRMSE |
|---|---|---|---|---|---|
| Case 1 | (1,2,3,4,5) | 0.2972 | Case 11 | (1,2,4,5,6) | 0.2653 |
| Case 2 | (1,2,3,5,6) | 0.2454 | Case 12 | (1,2,5,6,7) | 0.3185 |
| Case 3 | (1,2,3,6,7) | 0.3715 | Case 13 | (1,2,4,6,7) | 0.3632 |
| Case 4 | (1,2,3,4,6) | 0.2325 | Case 14 | (2,3,4,5,6) | 0.3202 |
| Case 5 | (1,2,3,4,7) | 0.3585 | Case 15 | (2,3,5,6,7) | 0.3361 |
| Case 6 | (1,2,3,5,7) | 0.2226 | Case 16 | (2,4,5,6,7) | 0.377 |
| Case 7 | (1,3,4,5,6) | 0.2207 | Case 17 | (2,3,4,5,7) | 0.3025 |
| Case 8 | (1,3,4,6,7) | 0.3377 | Case 18 | (2,3,4,6,7) | 0.4024 |
| Case 9 | (1,3,4,5,7) | 0.2758 | Case 19 | (3,4,5,6,7) | 0.2284 |
| Case 10 | (1,4,5,6,7) | 0.2833 | Case 20 | (1,2,4,5,7) | 0.2989 |

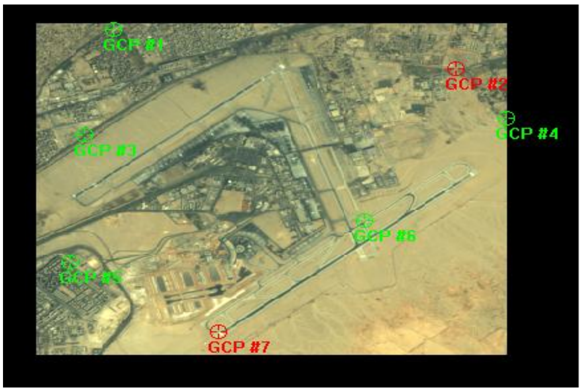



**Fig -6:** Distribution of used GCPs [Green Color] and Distribution of CPs [Red Color] in case of study number (7) for the second scenario that gives the best TRMS error

**Table 5 :** List of Error Result of used GCPs (A) and CPs (B) in case of study number 7 of second scenario

(A)

| Control point Error: (x) = 0.1583, (y) = 0.1539<br>Total RMS = 0.2207 | | | | |
|---|---|---|---|---|
| **GCP Point ID** | **Residual** | | **Result** | |
| | **X** | **Y** | **Contrib.** | **RMSE** |
| GCP # 1 | 0.17 | -0.029 | 0.78 | 0.172 |
| GCP # 3 | -0.286 | 0.144 | 1.45 | 0.32 |
| GCP # 4 | -0.032 | -0.142 | 0.66 | 0.146 |
| GCP # 5 | 0.111 | -0.182 | 0.967 | 0.213 |
| GCP # 6 | 0.037 | 0.208 | 0.958 | 0.212 |

(B)

| Check point Error: (x) = 0.6648, (y) = 0.4288<br>Total = 0.7911 | | | | |
|---|---|---|---|---|
| **CP Point ID** | **Residual** | | **Result** | |
| | **X** | **Y** | **Contrib.** | **RMSE** |
| CP # 2 | 0.694 | 0.028 | 0.878 | 0.695 |
| CP # 7 | 0.634 | -0.606 | 1.108 | 0.877 |

**Table 6**shows TRMS in each case of study in third scenario. **Fig - 7**show the distribution of used GCPs [Green Color] and remaining GCP which used as CP [Red Color] in the case (1) that gives higher accuracy with minimum Total RMS and **Table 7**

**Fig -6** (A and B) shows list of used GCPs in this case of study with RMS in X and Y coordinates and list of remaining points which used as check points with errors in X and Y coordinate in this case of study respectively.

**Table 6 :** Total RMS error in each case of scenario (3) when applying 1st order polynomial

| Cases of Study | Used GCPs | TRMS E | Cases of Study | Used GCPs | TRMS E |
|---|---|---|---|---|---|
| Case 1 | (1,2,3,4,5,6) | 0.2945 | Case 4 | (1,2,4,5,6,7) | 0.3481 |
| Case 2 | (1,3,4,5,6,7) | 0.3157 | Case 5 | (1,2,3,4,5,7) | 0.3329 |
| Case 3 | (2,3,4,5,6,7) | 0.3676 | Case 6 | (1,2,3,4,6,7) | 0.3964 |

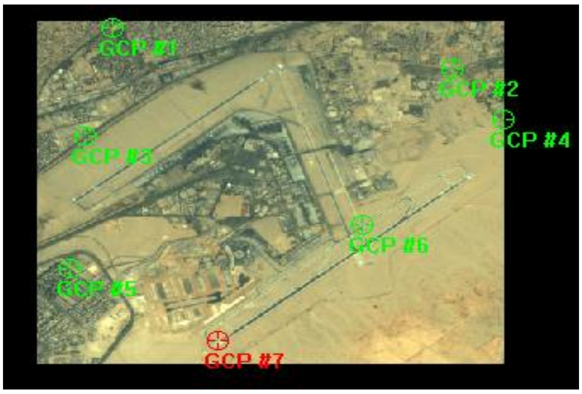



**Fig - 7:**Distribution of used GCP [Green Color] and Distribution of CPs [Red Color] in case (1) for the third scenario that gives the best Total RMS error

**Table 7 :** List of Error Result of used GCPS (A) and CPS (B) in case of study number 1 of third scenario

(A)

| Control point Error: (x) = 0.2587, (y) = 0.1407<br>Total RMS = 0.2945 | | | | |
|---|---|---|---|---|
| **GCP Point ID** | **Residual** | | **Result** | |
| | **X** | **Y** | **Contrib.** | **RMSE** |
| GCP # 1 | 0.034 | -0.034 | 0.163 | 0.048 |
| GCP # 2 | 0.398 | 0.016 | 1.353 | 0.398 |
| GCP # 3 | -0.3 | 0.144 | 1.13 | 0.333 |
| GCP # 4 | -0.308 | -0.153 | 1.169 | 0.344 |
| GCP # 5 | 0.232 | -0.177 | 0.991 | 0.292 |
| GCP # 6 | -0.055 | 0.205 | 0.72 | 0.212 |

(B)

| Check point Error: (x) = 0.7380, (y) = 0.6017<br>Total = 0.9522 | | | | |
|---|---|---|---|---|
| **CP Point ID** | **Residual** | | **Result** | |
| | **X** | **Y** | **Contrib.** | **RMSE** |
| CP # 7 | 0.738 | 0.602 | 1 | 0.952 |

Fig -8 show the distribution of seven GCPs in the fourth scenario that we use all the available GCP so there is no remaining point for using as check points and**Table 8** shows list of used GCPs in this case of study with RMS in X and Y coordinates.


**Fig -8:** Distribution of seven GCP for fourth scenario

**Table 8 :** List of used GCPS in case of study of fourth scenario

(A)

| **Control point Error: (x) = 0.2587, (y) = 0.1407**<br>**Total RMS = 0.2945** | | | | |
|---|---|---|---|---|
| **GCP Point ID** | **Residual** | | **Result** | |
| | **X** | **Y** | **Contrib.** | **RMSE** |
| GCP # 1 | 0.177 | -0.151 | 0.632 | 0.232 |
| GCP # 2 | 0.45 | -0.026 | 1.226 | 0.451 |
| GCP # 3 | -0.338 | 0.175 | 1.036 | 0.381 |
| GCP # 4 | -0.346 | -0.122 | 0.999 | 0.367 |
| GCP # 5 | -0.027 | 0.034 | 0.119 | 0.044 |
| GCP # 6 | -0.0261 | 0.455 | 1.238 | 0.455 |
| GCP # 7 | 0.347 | 0.447 | 1.216 | 0.447 |

## 5.2 Results in Case of Using Second Order polynomial

Geometric correction needs 7 GCPs as minimum number of control points as calculated from Equation (3). The available GCPs is seven so, the objective of this step of research is to test the suitability of given GCPs for geometric correction of input image. It is investigated by the accuracy check that is applied by calculating Total RMS of the calculated transformation process.

Fig -9 illustrates a flow chart of work flow of in case of using first order polynomial showing the cases of study for each group of available GCPs.

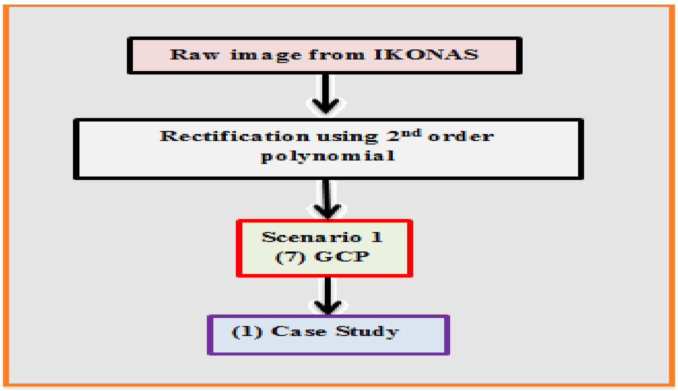



**Fig -9:** A flow chart of work flow in case of using 2nd order polynomial

**Table 9**shows list of used GCPs in this case of study with RMS in X and Y coordinates of the geometric correction process when using all available GCPs with distribution shown in Fig -10.

**Table 9 :** List of used GCPS in case of study using second order polynomial

(A)

| Control point Error: (x) = 0.0169, (y) = 0.0375<br>Total RMS = 0.0411 | | | | |
|---|---|---|---|---|
| **GCP** | **Residual** | | **Result** | |
| **Point ID** | **X** | **Y** | **Contrib.** | **RMSE** |
| GCP # 1 | 0.01 | 0.027 | 0.711 | 0.029 |
| GCP # 2 | -0.004 | -0.005 | 0.167 | 0.007 |
| GCP # 3 | -0.029 | -0.0064 | 1.706 | 0.07 |
| GCP # 4 | 0.011 | -0.008 | 0.326 | 0.013 |
| GCP # 5 | 0.028 | 0.049 | 1.378 | 0.057 |
| GCP # 6 | -0.005 | 0.035 | 0.87 | 0.036 |
| GCP # 7 | -0.011 | -0.035 | 0.892 | 0.037 |


**Fig -10:** Distribution of seven GCP when applying 2nd order polynomial

## 6. CONCLUSIONS

Image geometric correction depends on the available georeferencing data. Ground control points are considered as more accurate georeferencing data although they need ground surveying process that may be costly. It is important to know the requirements that meet the need of used algorithms for geometric correction application. The research ended up with the optimum requirements of geometric correction for remote sensing images when ground control points are available. The research results are based on real data that used seven available GCPs to correct RGB image from IKONOS satellite sensor.

The minimum requirements of used GCPs depend on the used order of polynomials and the order of used polynomial depends on the available GCPs. The available GCPs are seven so, geometric correction process is controlled to use just first or second order polynomials. First order polynomial gave more accurate results than others from using second order polynomial. The first order polynomial gave accurate results when using just four GCPs. So, four GCPs are enough for geometric correction for remote sensing satellite image in case of using first order polynomial with distribution same like used in the research as possible.

The research succeeded in identifying the optimum number of CGPs and their distribution that helps the surveyor in setting up the GCPs in the field. The optimum number of GCPs is the minimum required number of GCPs with well distribution when using first order polynomial that tends to saving in financial and computational costs.

## REFERENCES

[1] Baboo, S.S. and S. Thirunavukkarasu, Geometric Correction in High Resolution Satellite Imagery using Mathematical Methods: A Case Study in Kiliyar Sub Basin. Global Journal of Computer Science and Technology, 2014. 14(1-F): p. 35.

[2] Toutin, T., Review article: Geometric processing of remote sensing images: models, algorithms and methods. International Journal of Remote Sensing, 2004. 25(10): p. 1893-1924.

[3] Dave, C.P., R. Joshi, and S. Srivastava, A Survey on Geometric Correction of Satellite Imagery. International Journal of Computer Applications, 2015. 116(12).

[4] Phetcharat, S., M. Nagai, and T. Tipdecho, Influence of surface height variance on distribution of ground control points. Journal of Applied Remote Sensing, 2014. 8(1): p. 083684-083684.

[5] ERDAS Field Guide™ Fifth Edition,Revised and Expanded, CHAPTER 9 "Rectification". 2013.

[6] Ok, A. and M. Turker. Comparison of different mathematical models on the accuracy of the orthorectification of ASTER imagery. in XXth ISPRS Congress: Geo-imagery bridging continents. 2004.

[7] Hosseini, M. and J. Amini, Comparison between 2-D and 3-D transformations for geometric correction of IKONOS images. ISPRS, Hannove. www. isprs. org/ publications/ related/ hannover05/ paper, 2005.

[8] OO, K.S., Reliable Ground Control Points for Registration of High Resolution Satellite Images. 2010.

[9] Eltohamy, F. and E. Hamza. Effect of ground control points location and distribution on geometric correction accuracy of remote sensing satellite images. in 13th International Conference on Aerospace Sciences & Aviation Technology (ASAT-13). 2009.

[10] Baboo, S.S. and M.R. Devi, Geometric correction in recent high resolution satellite imagery: a case study in Coimbatore, Tamil Nadu. International Journal of Computer Applications, 2011. 14(1): p. 32-37.

[11] Babiker, M.E.A. and S.K.Y. Akhadir, The Effect of Densification and Distribution of Control Points in the Accuracy of Geometric Correction. 2016.

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