# GEOMETRIC TRANSFORMATION OF GOOGLE EARTH IMAGERY TO GENERATE ORTHOPHOTO IMAGES FOR SURVEY PRACTICES

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## ABSTRACT

In this paper, effort has been made to geo-transform Google Earth imagery. The first order polynomial (Affine) method of geometric transformation was used to register imagery obtained from Google Earth using ArcMap 9.3 software. The real-world coordinates of Ground Control Points (GCPs) used in geo-transforming the image was obtained with Leica GX1230 GPS in static mode. The geometric accuracy of the initial transformed image was 0.04066m RMSE, and 0.00057m RMSE for the rectified image. To further test the accuracy of the image produced, a landed property from a geodetic GPS survey was overlaid on the imagery and a significant result was obtained. The analysis of the results obtained revealed low resolution of the imagery produced, which indicated that the geo-transformation of Google Earth imagery is not good enough for geodetic or large scale engineering purposes. However, it can be inferred that the geometric transformation of Google Earth imagery is an alternative tool for generating imagery for cadastral and small scale engineering surveys.

**Keywords:** Geometric Transformation, Google Earth Imagery, Ground Control Points, Orthophoto, Real-World Coordinates, and Resampling,

## INTRODUCTION

The advancement of computer technology in Digital Photogrammetry, Remote Sensing, and Geographic Information Systems (GIS) is enabling earth observation at a very high resolution. These developments have also revolutionarized the field of cadastral surveys. The high resolution satellite imagery is showing its usefulness for cadastral surveys due to which traditional cadastre and land registration systems have been undergoing major changes worldwide (Zahir, 2012). Orthophoto maps produced from aerial photographs or satellite images are now used to test the quality of cadastral plans.

Many GIS companies are engaged in providing users with high resolution orthorectified aerial photographs or satellite images. Some of these companies include TomTom, NAVTEQ, Data Depot, Map-Mart and LAND INFOR International (Chang, 2014). Alhough GIS companies provide orthorectified aerial photographs and satellite images, the high cost of such products impedes the use of imageries for cadastral practices.

Google earth, a free online mapping service provider uses digital elevation models (DEM), satellite imagery, and aerial photographs to display three dimensional (3D) maps of the Earth's surface. Most land areas are covered in satellite imagery with a resolution of about 15m per pixel. This base imagery is 30m multispectral Land Sat which is pan sharpened with the 15m (panchromatic) Land Sat imagery. However, Google is actively replacing this base imagery with 2.5m SPOT Image imagery and several higher resolution datasets. Some population centres are also covered by aircraft imagery (orthophotography) with several pixels per meter. The images are not all taken at the same time, but generally current to within three years (Wikipedia, 2014).

Surveyors integrate cadastral plans or maps generated from a GIS package with Google Earth. Maps or plans can be converted from Environmental Systems Research Institute (ESRI) shape file to Keyhold Markup Language (KML) file and imported into Google Earth. This enables the Surveyor determine the degree of accuracy of the survey to some extent. However, there are two basic problems that may arise from such use of Google Earth imagery. The first one is that the positional accuracy of Google Earth imageries is low. The second problem is the consistent use of the internet which hinders its use for cadastral practices particularly in developing countries with poor internet services (www.ijmse.org/).

This research therefore focuses on the use of Google Earth Imagery and Global Positional System (GPS) to produce orthophoto images for survey practices. The study demonstrated in a logical order how orthophotos can be generated from Google Earth Imagery using geometric transformation technique. The use of these orthophotos as input to GIS-based cadastral information system is highly advocated, particularly for regional surveys in Africa.

## Geometric Transformation

Geometric Transformation is the process of using a set of control points and transformation equations to register a digitized map, a satellite image, or an aerial photograph on to a projected coordinate system (Britz, 2003). Remotely sensed imagery collected from airborne or space borne sensors often contain internal and external geometric errors. These errors can be systematic or non-systematic (random) (Baboo and Devi, 2011). Transformation can correct geometric errors in the remotely sensed data, which are caused by the relative motions of a satellite and uncontrolled variations in position and altitude of the remote sensing platform. Basically, there are two types of geometric transformation: map-to-map and image-to-map transformation (Work, 2016). Map-to-map transformation converts newly digitized map into projected coordinates system, while image-to-map transformation changes the rows and columns of a satellite image into projected coordinates. Both techniques use a set of control points to establish a mathematical model that relates the coordinates of one system to another. Details of these two methods are found in Chang (2014).

## Control Points

Control points play a vital role in determining the accuracy of a transformation. For an image-to-map transformation, ground control points (GCPs) are selected at points where both image coordinates and real-world coordinates are identified. The GCPs are selected directly from a satellite image. There are those features that show up clearly as single distinct pixels. Examples include wall fence intersection lines, road junctions and others. Real-world coordinates of GCPs are obtained from digital maps or GPS surveys after they are identified on both image and ground.

## Geometric Transformation Equations

Having generated equations that fit the GCPs data, least squares method is used to model the corrections. Depending on the distortion in the imagery, the number of GCPs used, and the degree of topographic relief displacement in the area, higher-order polynomial equations are required to geometrically correct the data. Among the different methods of transformation, the affine transformation method was adopted for the purpose of this study. This method is mathematically expressed as (Chang, 2014 and *www-math.ucdenver.edu/*).

$$X = Ax + By + C \tag{1}$$

$$Y = Dx + Ey + F \tag{2}$$

where, X and Y are the coordinates of GCPs; x and y are input coordinates that were given on the image; and A, B, C, D, E, and F are the affine transformation coefficients.

The following matrix form of least squares equation is used to solve for the transformation coefficients (Chang, 2014):

$$
\begin{bmatrix} C & F \\ A & D \\ B & E \end{bmatrix} = \begin{bmatrix} n & \Sigma x & \Sigma y \\ \Sigma x & \Sigma x2 & \Sigma xy \\ \Sigma y & \Sigma xy & \Sigma y2 \end{bmatrix} . \begin{bmatrix} \Sigma X & \Sigma Y \\ \Sigma xX & \Sigma xY \\ \Sigma yX & \Sigma yY \end{bmatrix} \tag{3}
$$

The coefficient C represents the translation in the x direction and F the translation in the y direction. Other properties such as rotation, skew, and scale are derived from the equations below (Chang, 2014):

$$A = SxCos(t) \tag{4}$$
$$B = Sy[kCos(t) - Sin(t)] \tag{5}$$
$$D = SxSin(t) \tag{6}$$
$$E = Sy[kSin(t) + Cos(t)] \tag{5}$$

where $Sx$ is the change of scale in x axis, $Sy$ is the change of scale in y axis, $t$ is the rotation angle, and $k$ is the shear factor.

## Root Mean Square (RMS) Error

The location of a control point on a digitized map or an image is an estimated location and can deviate from its actual location. The RMS error is a measure of the deviation between the actual location and the estimated location of the control points in geometric transformation (Mikhail and Gracie (1981). After the six transformation coefficient in Eq. 3 are determined, the image (or digitized) coordinates of the first control points are used as inputs ($x \ and \ y$ values) in Eq. (1) and (2). Thus the X and Y values are computed respectively. If the control point was perfectly located on the image, the computed X and Y values would be the same as the real-world coordinates of the control point. However, this is rarely the case. The differences between the computed and the real-world coordinates become errors associated with the first control point on the output.

Generally, the RMS Error is computed by (Chang, 2014):

$$\sqrt{[(x_{act} - x_{est})^2 + (y_{act} - y_{est})^2]} \tag{8}$$

where $x_{act}$ and $y_{act}$ are the $x$ and $y$ values of the actual location, and $x_{est}$ and $y_{est}$ are the $x$ and $y$ values of the estimated location.

The average RMS error is computed by averaging errors from all control points (Chang, 2014):

$$\sqrt{\left\{\left[\sum_{i=1}^{n}\left(x_{act,\ i} - x_{est,\ i}\right)^2 + \frac{\sum_{i=1}^{n}\left(y_{act,\ i} - y_{est,\ i}\right)^2\right]\right\}} \tag{9}$$

where $n$ is the number of control points, $x_{act,\ i}$ and $y_{act,\ i}$ are the $x$ and $y$ values of the actual location of control point $i$, and , and , are the and values of the estimated location of control point . The RMS error should be within tolerance to ensure the accuracy of the geometric transformation. The tolerance value is defined by the image resolution or map scale. For an image with 30m resolution, a RMS error of < 1 pixel is probably acceptable. A map with a scale of 1:24,000 is expected to have a RMS error of < 6m (Chang, 2014).

The assumption is that if the same level of accuracy applies to the entire map or image, the RMS error based on the control points is within the acceptable range. However, this assumption may not be true under certain circumstances as explained in Chang (2014). The control points needs to be adjusted if the RMS error exceeds the established tolerance value. This mean removing the control points that contribute most to the RMS error and replacing them with new ground control points. The process is repeated until a satisfactory RMS is obtained.

## Resampling

Resampling is a process of filling each pixel of a newly transformed image with a value or a derived value from the original image(Dodgson, 1992). After the geometric transformation of a satellite image, the cell centres of the input image rarely match with the cell centres on the output image; however, values need to be assigned to the centres. During transformation, a matrix of empty cells is computed using the map or image coordinates. Each empty cell is given a value based on the resampling process (ESRI, 2008). The three most common resampling techniques listed in order of increasing complexity and accuracy are: nearest neighbor, bilinear interpolation, and cubic convolution. Details of these resampling methods can be found in ESRI (2008) and Chang (2014).

## MATERIALS AND METHODS

The imagery of the test site used in this study (Figure 1) was acquired from Google Earth (2015) through its official web site (http://www.earth.google.com). The imagery was obtained in Joint

Photographic Experts Group (JPEG) file format with 1587 columns and 1122 rows. The image spatial reference was undefined.

After acquiring the imagery, the test site was visited. With the aid of the printed imagery and geographical coordinated extracted online from Google Earth, the test site was successfully located. After touring the entire site, wall fence intersection lines that were identified and clearly marked both on imagery and on ground.



Figure 1: Google Earth Imagery for the Test Site with GCPs marked.

## 7.1 GCPs Real-World Coordinates

The Global Positioning System survey was carried out to obtain the real-world coordinates of the Ground Control Points (GCPs). Two Leica Geodetic GPS receivers (GX1230) were used in static relative mode for ten minutes per station with epoch rate of 15 seconds. The GCPs were clear from obstructions. Raw GPS data were processed using Leica Geo Office (LGO) 8.1 software. The average standard deviation of the coordinates of the GCPs after adjustment with LGO was 0.012m in latitude and 0.014m in longitude. Using Circular Error Probability (R95) [the radius of circle centred at the true position, containing the position estimate with probability of 95%] as a statistical tool to determine how accurate the acquired data was indicates that the coordinate values of

the GCPs were 0.032m close to their true values. The R95 formula and other GPS accuracy measures can be found in NovAtel (2003).

The coordinates obtained with GPS were geographical with reference to WGS-1984 datum. These coordinates were converted to WGS-1984 UTM Zone 32N coordinates system using a programmed Casio Fx-9860G11 calculator. The UTM coordinates were subsequently used to geo-reference the image.

## Image Transformation

The image was transformed using the first order polynomial (Affine) method of transformation in ArcGIS 9.2. The JPEG image of the Test Site was added into ArcMap windows. With the printed and marked copy on hand, the 24 control points were successfully added. To input the GCPs real- intersection world coordinates, the View Link Table icon on the Georeferencing toolbar was clicked. The Link Table appeared and the UTM coordinates entered accordingly as shown in Figure 2. After geo-transforming the image, its orientation changed as shown in Figure 3 below.
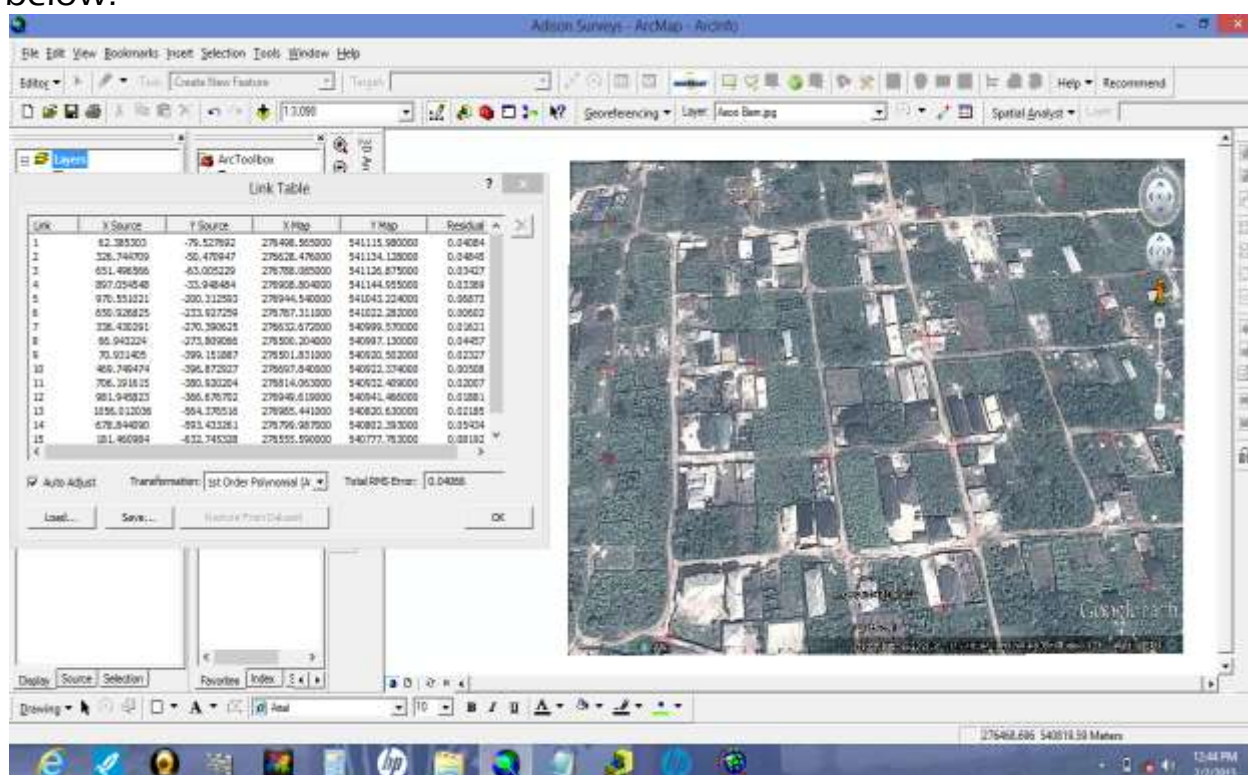


Figure 2: Geometric Transformation of the Image Using ArcMap

For an image to be truly geo-transformed, its four corners must be included in the control points used to transform it. In this study however, it was not possible for the researchers to identify these points on the ground. Hence, their coordinates were not captured during the GPS

observation. In order to generate an image that is truly geo-transformed, the authors chose four points that formed the extents of the final image. These points were selected in such a way that they are all within the GCPs used in transforming the image. In Figure 3, the extents are indicated by red lines, and the coordinates of the intersection of these lines were extracted.
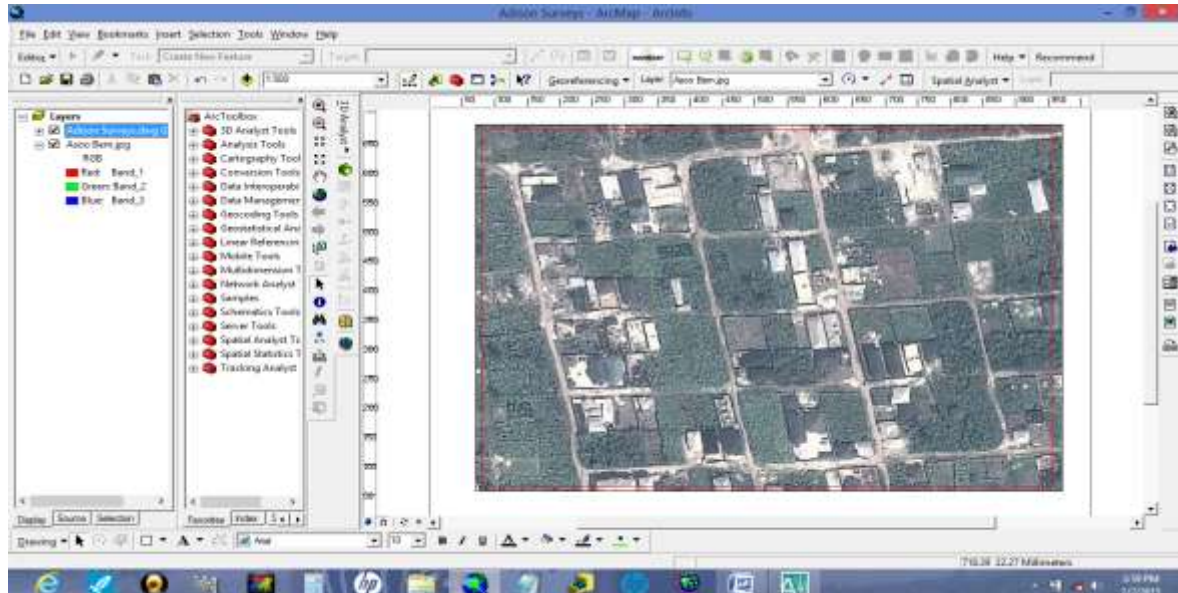

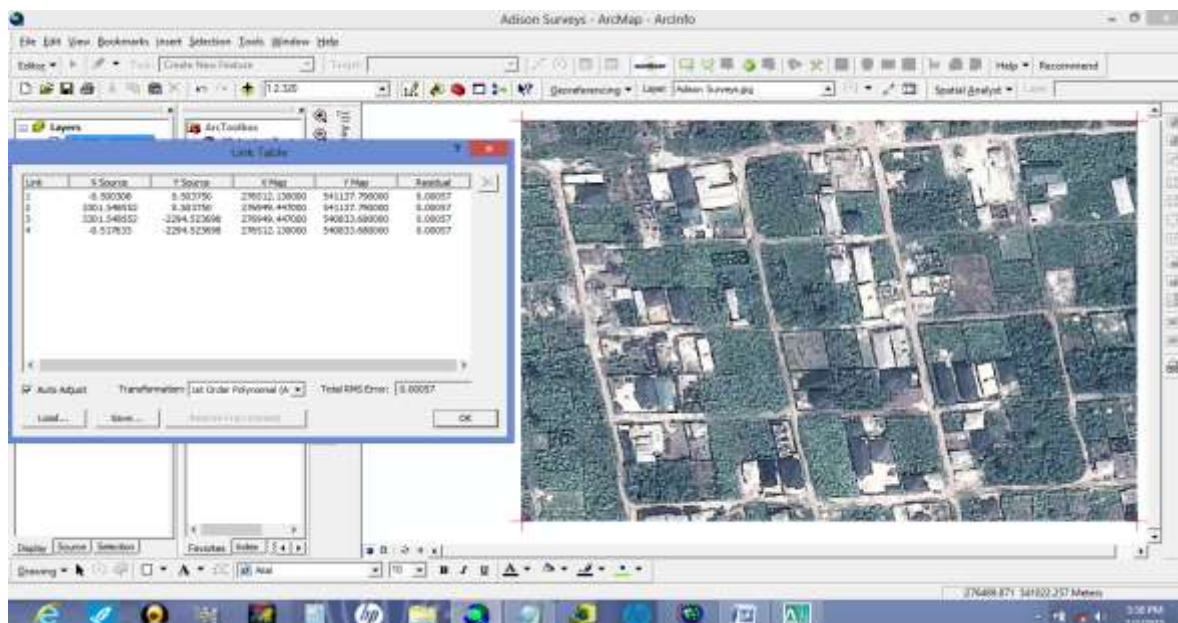
Figure 3: The Initial Transformed Image



Figure 4: Final Process of the Image Transformation

The transformed image was exported into JPEG file format. The file was cropped in Microsoft Office Picture Manager so that areas outside the selected four corner points were eliminated. The edited JPEG file was

added into ArcMap, and final transformation performed now using only the four corner points as control points as shown Figure 4. The resulting image was rectified and resampled using nearest neighbor method in ArcMap. The final image was saved in ERDAS IMAGINE file format as Adison_Surveys.img shown in Figure 5.

## RESULTS

Table 1 show the input and output coordinates of the control points used in registering (geo-transforming) the image. Columns 2 and 3 of Table 1 show the easting and northing of input coordinates. Columns 4 and 5 show the control points easting and northing real-world (output) coordinates in meters based on the WGS-84 UTM Zone 32N coordinates system obtained in the field using GPS. Column 6 shows deviations (RMS Errors) or residuals between input and output location of the control points while the bottom right corner show the total (average) RMS error. As described earlier, the image was not entirely geo-referenced using input and out coordinates of control points shown in Table 1. This is because some parts of the image are outside the GCPs used. Hence, an area totally covered by the control points was marked and exported to JPEG file. Table 2 show the input and output coordinates of the image four corners used as control points to geo-transform the final image. Figure 5 show the rectified image saved in ERDAS IMAGINE file format.

## Table 1: Input and output coordinates of control points used for the first transformation

| Link | X Source | Y Source | X Map | Y Map | Residual |
|------|----------|----------|-------|-------|----------|
| 1 | 62.385303 | -79.527692 | 276498.565000 | 541115.980000 | 0.04084 |
| 2 | 326.744709 | -50.470947 | 276628.476000 | 541134.128000 | 0.04845 |
| 3 | 651.496566 | -63.005229 | 276788.085000 | 541126.875000 | 0.03427 |
| 4 | 897.054548 | -33.948484 | 276908.804000 | 541144.955000 | 0.03369 |
| 5 | 970.551021 | -200.312593 | 276944.540000 | 541043.224000 | 0.06873 |
| 6 | 650.926825 | -233.927259 | 276787.311000 | 541022.282000 | 0.00602 |
| 7 | 336.430291 | -270.390625 | 276632.672000 | 540999.570000 | 0.01621 |
| 8 | 66.943224 | -273.809066 | 276500.204000 | 540997.130000 | 0.04457 |
| 9 | 70.931405 | -399.151887 | 276501.831000 | 540920.502000 | 0.02327 |
| 10 | 469.749474 | -396.872927 | 276697.840000 | 540922.374000 | 0.00508 |
| 11 | 706.191615 | -380.920204 | 276814.063000 | 540932.409000 | 0.02007 |
| 12 | 981.945823 | -366.676702 | 276949.619000 | 540941.466000 | 0.01881 |
| 13 | 1056.012036 | -564.376516 | 276985.441000 | 540820.630000 | 0.02185 |
| 14 | 678.844090 | -593.433261 | 276799.987000 | 540802.393000 | 0.05434 |
| 15 | 181.460984 | -632.745328 | 276555.590000 | 540777.763000 | 0.08192 |

☑ Auto Adjust    Transformation: 1st Order Polynomial (A ▼    Total RMS Error: 0.04066

## Table 2: Input and output coordinates of control points used for transforming the final image



| Link | X Source | Y Source | X Map | Y Map | Residual |
|---|---|---|---|---|---|
| 1 | -0.500308 | 0.503750 | 276512.130000 | 541137.790000 | 0.00057 |
| 2 | 3301.548552 | 0.503750 | 276949.447000 | 541137.790000 | 0.00057 |
| 3 | 3301.548552 | -2294.523698 | 276949.447000 | 540833.680000 | 0.00057 |
| 4 | -0.517633 | -2294.523698 | 276512.130000 | 540833.680000 | 0.00057 |

Auto Adjust    Transformation: 1st Order Polynomial (A    Total RMS Error: 0.00057

Load...    Save...    Restore From Dataset    OK



Figure 5:  Rectified Photo Image

## DISCUSSION

From the result presented above, it is clear that the transformation of the entire image is acceptable. The average deviation between the input and output location of the control points is 0.04066m in the first

transformation and 0.00057m in the final transformation, all based on the WGS-84 UTM Zone 32N coordinates system.

As stated above a RMS error of < 1 pixel is acceptable for an image with 30m resolution. Since, Google Earth imagery is generally with a resolution of between 15m to 30m, RMS error of < 1 pixel (cell size) is acceptable. The image has a cell size of 0.132 units. Comparing this value with the average RMS error in Table 1 (which is 0.04066) and Table 2 (which is 0.00057) indicates that the geometric transformation of the entire image is accurate enough for cadastral purposes. The assumption that the entire image or map transformed is accurate if RMS error is within tolerance sometimes is ambiguous. To ensure that the Google Earth imagery was accurately registered a landed property within the Test Site surveyed by Amadi (2013) using a geodetic GPS was overlaid on the rectified image. The result shown in Figure 6 below further confirmed that the geometric transformation of the image was accurately done.



Figure 6: Plan No.: JWA/RS/2013/069 Overlaid on the geo-transformed image.

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## CONCLUSION

In a detail, simple and logical order, it has been revealed that Google Earth imagery can be utilized for cadastral survey practices. From the analysis, it is clear that the technique is suitable for both small and large scale cadastral surveys. Though the method produced geo-referenced images from Google Earth with an acceptable RMS error, the resolution of the image produced is low. For instance, the image of the Test Site produced from this study coarse such that one is not able to distinguish the features on the image if zoomed below the scale of 1:200. Thus geo-transformed imagery of Google Earth may not be good enough for geodetic and large scale engineering work, but is an alternative tool in generating imagery for cadastral and small scale engineering surveys.

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