

## Analysis and Correction of Vector Data Generated from Multi-Temporal Satellite Imagery of Google Earth by Means of Mathematical Formulas

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### Abstract

In this era of twenty first century, Google Earth (GE) delivered tangible advantage to the users. The reliability of people searching the geographical location of the earth on GE service increases and to use its geospatial information for different mapping purposes due to its high spatial resolution of raster data and other ancillary information. The study aimed to generate three separate vector layers from three different time-series satellite data of GE on the same geographical location of the earth. Since the vector layers were superimposed in a particular frame, it was observed that layers were found to be not congruent, as the multi-temporal satellite imagery of GE were shifted from one another. In order to examine the shifted error and to rectify the geometric distortion of vector data, the mathematical formulas were used in the study. Initially, Haversine formula was used to measure the shifted distance between the corresponding points of vector layers. After calculating the distance values of two corresponding points, Lagrange form of Interpolation Polynomial formula was applied to minimize the distance value of vector layers. However, this formula did not provide a satisfying result to reduce the average distance value of vector data. Finally, Affine transformation formula was fit to reduce the distance value and to rectify the geometric distortion of vector layers in comparison with Lagrange form of Interpolation Polynomial formula. Therefore, in order to obtain the correct vector data, the geometric correction of data was required for any 'Change Detection' study on multi-temporal satellite imagery of GE.

**Keywords:** Google earth; Vector data; Haversine law; Lagrange form of interpolation polynomial; Affine transformation

### Introduction

Google Earth (GE), a virtual globe geo-browser software was initially developed to fulfill the ideas of Digital Earth project after the announcement of US Vice-President Al Gore in 1998 [1]. Since June, 2005, the interest of people increases working with GE data as it was openly accessible to the users. The massive raster data of GE is composed of zillions of separate satellite images, which are acquired from the sensor of satellite or space shuttle [2]. GE not only provides a worldwide raster data with high spatial resolution but also helps in detailed analysis of the vector data. The Shuttle Radar Topography Mission (SRTM) data is also incorporated in GE application to generate 3D view of entire earth. Many geospatial data have been integrating in GE technology from time to time. The data files provided by GE are in the Keyhole Markup Language (KML) standard that enables the users to create and organize the information as per their requirement [3]. It would be relevant to say that most of the educators and researchers have been using the GE data for the purpose of their scientific research work as the embedded geospatial data are freely accessible online. However, the horizontal inaccuracy of multi-temporal satellite imagery of GE leads to inappropriate data generation of a specific location. The focus of this study is to rectify the shifted vector data generated from the multi-temporal satellite imagery of GE by using mathematical formulas.

In the present study, the area of interest is located in the south eastern part of Bankura town in the state of West Bengal, India. The three distinct vector layers are generated on the basis of four permanent points, which are discernible in multi-temporal satellite imagery of GE and found to be not congruent, as different time period data of GE are shifted. The objective of this study is to examine the generated vector data by using Haversine formula and further to rectify the data by means of Lagrange form of Interpolation Polynomial and Affine transformation formula.

### Methodology

The experiment has been initiated by identifying four distinct

permanent points on the GE satellite data of 16<sup>th</sup> December, 2016 by Add Placemark tool of GE in the South Eastern part of Bankura town, West Bengal, India. On the basis of these defined points, the vector layer is generated by using Add Polygon tool of GE software and the same is taken as the reference data of this study. The study requires different acquisition dates of satellite images of GE and the same is acquired by using Time Slider tool. The Time Slider tool of GE provides multi-temporal satellite imagery and enables the users to study the radical changes of any particular landscape which is affected by any kind of natural disasters in different time period [4]. The Time Slider tool is used to mark the defined permanent points on historical two series of GE satellite imagery i.e., 16<sup>th</sup> November, 2006 and 6<sup>th</sup> March, 2008. In the same way, the other two vector layers are generated by Add Polygon tool. The vector layers generated from GE satellite data of 16<sup>th</sup> December 2016, 16<sup>th</sup> November, 2006 and 6<sup>th</sup> March, 2008 are assigned as V1, V2 and V3 respectively. These vector layers are represented by three sets of data points i.e., A, B, C, D for V1, A', B', C', D' for V2, and A<sub>0</sub>, B<sub>0</sub>, C<sub>0</sub>, D<sub>0</sub> for V3. The data points of V1 i.e., A, B, C, D generated from marked permanent points of the ground on GE satellite imagery of 16<sup>th</sup> December, 2016 are shown in Figure 1.

Similarly, on the basis of same permanent points of the ground, A', B', C', D' for V2 and A<sub>0</sub>, B<sub>0</sub>, C<sub>0</sub>, D<sub>0</sub> for V3 are generated from GE satellite imagery of 16<sup>th</sup> November, 2006 and 6<sup>th</sup> March, 2008 respectively and these are shown in Figures 2 and 3.

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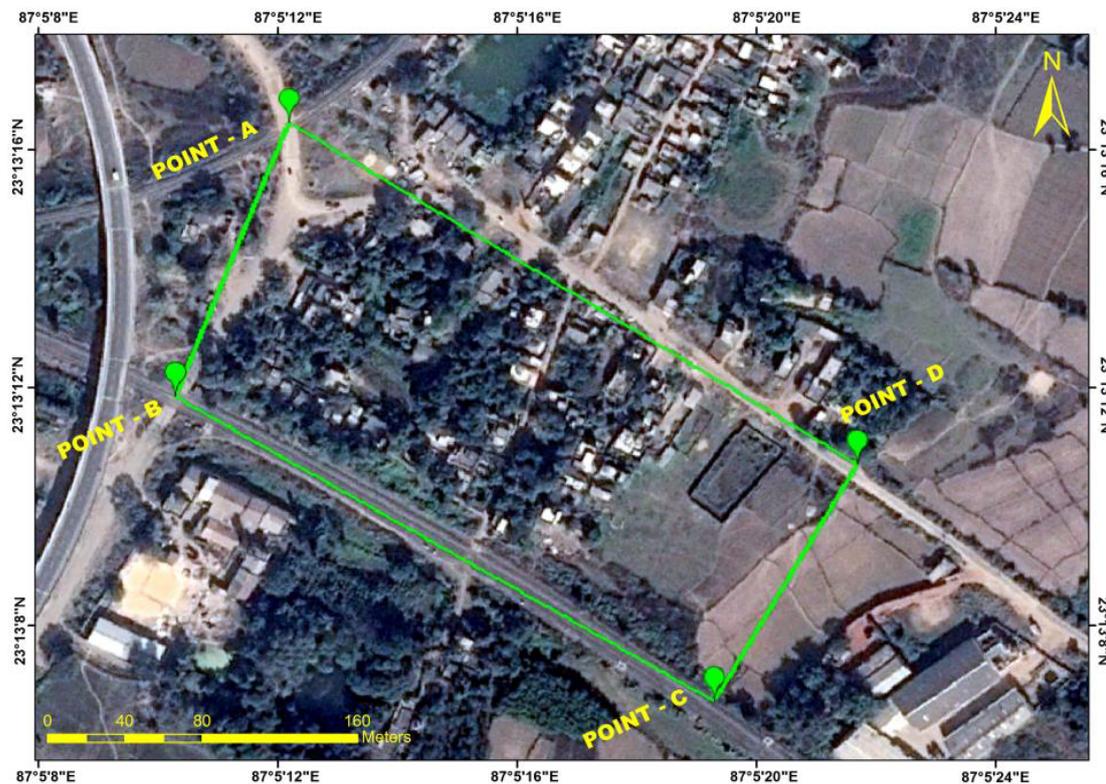


Figure 1: The permanent data points of the ground marked on GE satellite imagery of 16<sup>th</sup> December, 2016 are considered as A, B, C, D.

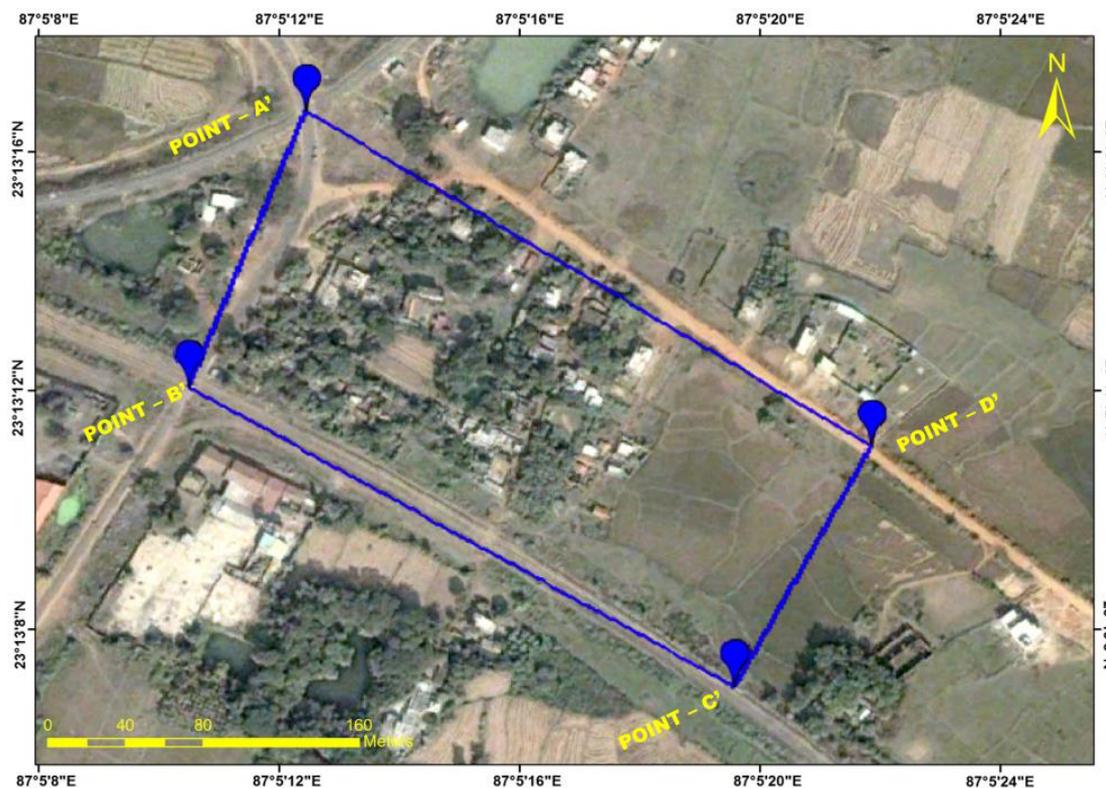


Figure 2: The same permanent points of the ground namely A', B', C', D' are defined on GE satellite imagery of 16<sup>th</sup> November, 2006.

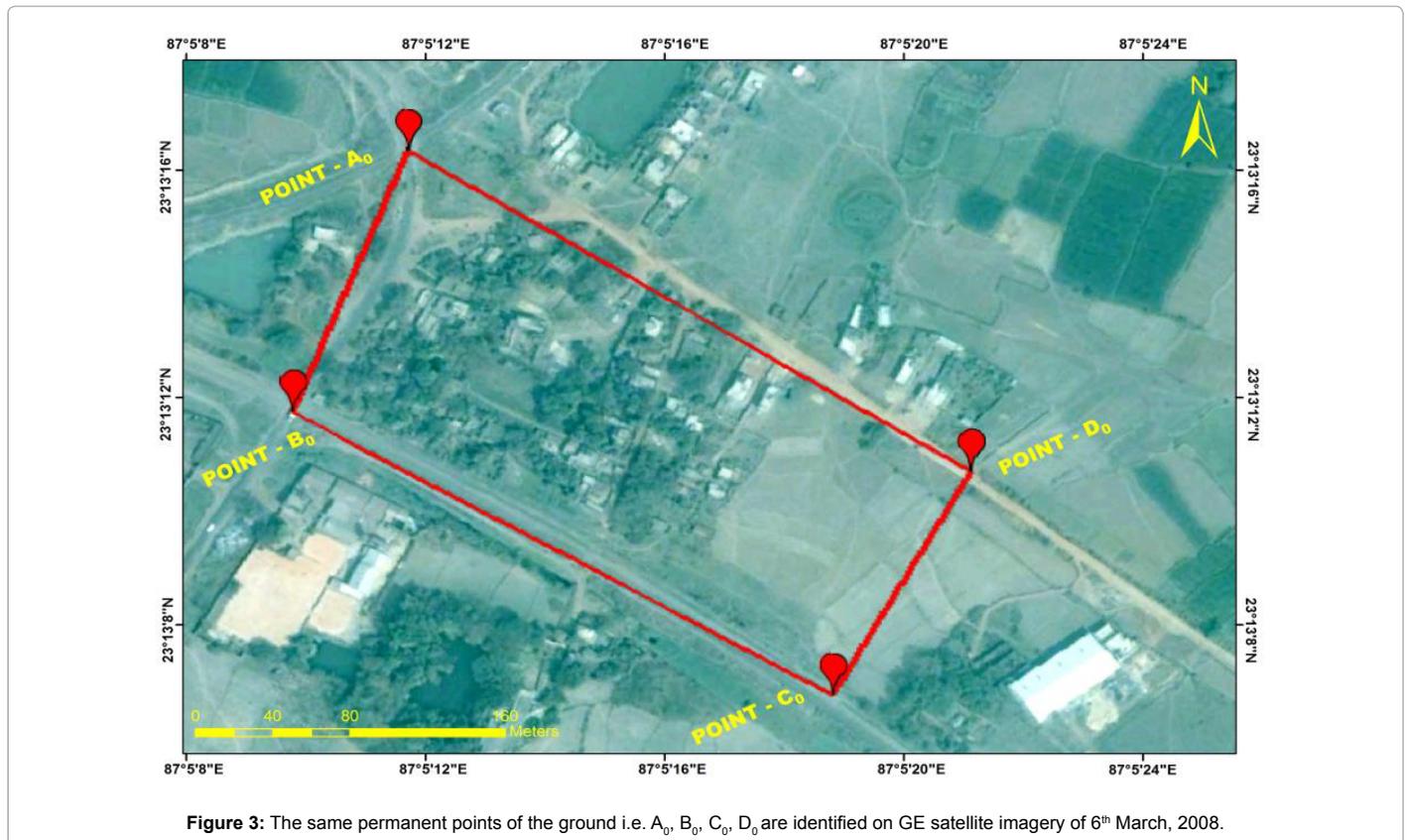


Figure 3: The same permanent points of the ground i.e. A<sub>0</sub>, B<sub>0</sub>, C<sub>0</sub>, D<sub>0</sub> are identified on GE satellite imagery of 6<sup>th</sup> March, 2008.

The above mentioned three sets of data points and their corresponding three vector layers (V1, V2 and V3) are overlaid simultaneously on GE satellite data of 16<sup>th</sup> December in 2016 and it is observed that these three sets of data points as well as these vector layers are shifted from one another in spite of being generated from the same permanent points of the ground as shown in Figure 4.

The coordinate values of three sets of data points are mentioned below:

- A=87°5'12.192"E and 23°13'16.439"N, B=87°5'10.298"E and 23°13'11.831"N,
- C=87°5'19.284"E and 23°13'6.744"N, D=87°5'21.7"E and 23°13'10.722"N.
- A'=87°5'12.399"E and 23°13'16.265"N, B'=87°5'10.486"E and 23°13'11.6"N,
- C'=87°5'19.537"E and 23°13'6.629"N, D'=87°5'21.858"E and 23°13'10.605"N.
- A<sub>0</sub>=87°5'11.719"E and 23°13'16.347"N, B<sub>0</sub>=87°5'9.78"E and 23°13'11.715"N,
- C<sub>0</sub>=87°5'18.825"E and 23°13'6.758"N, D<sub>0</sub>=87°5'21.16"E and 23°13'10.742"N.

### Haversine formula

The shifted distance between the corresponding points of these vector layers is measured by using Haversine formula. Haversine formula is an optimum formula in spherical trigonometry used in computing the shortest distance between two points on the surface of the earth. Haversine or 'half-versed-sine' can be written as

$$\text{hav } \varphi = \frac{1}{2}(1 - \cos \varphi) = \sin^2\left(\frac{\Delta\varphi}{2}\right), \text{ where } \text{hav } \varphi = \text{haversine of an angle [5].}$$

The basic formula of Haversine is represented as  $\text{hav } \varphi = \text{hav } \Delta\varphi + \cos \varphi 1 \cos \varphi 2 \text{ hav } \Delta\lambda$ , where 'a' is angular distance between two points on the spherical surface of the earth with their latitudes and longitudes [6].

This formula taken from Sinnott [7] is illustrated as follows:-

$$a = \sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos \varphi 1 \cos \varphi 2 \sin^2\left(\frac{\Delta\lambda}{2}\right) \quad (1)$$

$$c = 2 \cdot \text{atan2}\left(\sqrt{a}, \sqrt{1-a}\right)$$

$$d = R \cdot c$$

$\varphi 1, \lambda 1$  represent latitude and longitude value of first point.

$\varphi 2, \lambda 2$  represent latitude and longitude value of second point.

$\Delta\varphi$  is the difference in latitudes between two points.

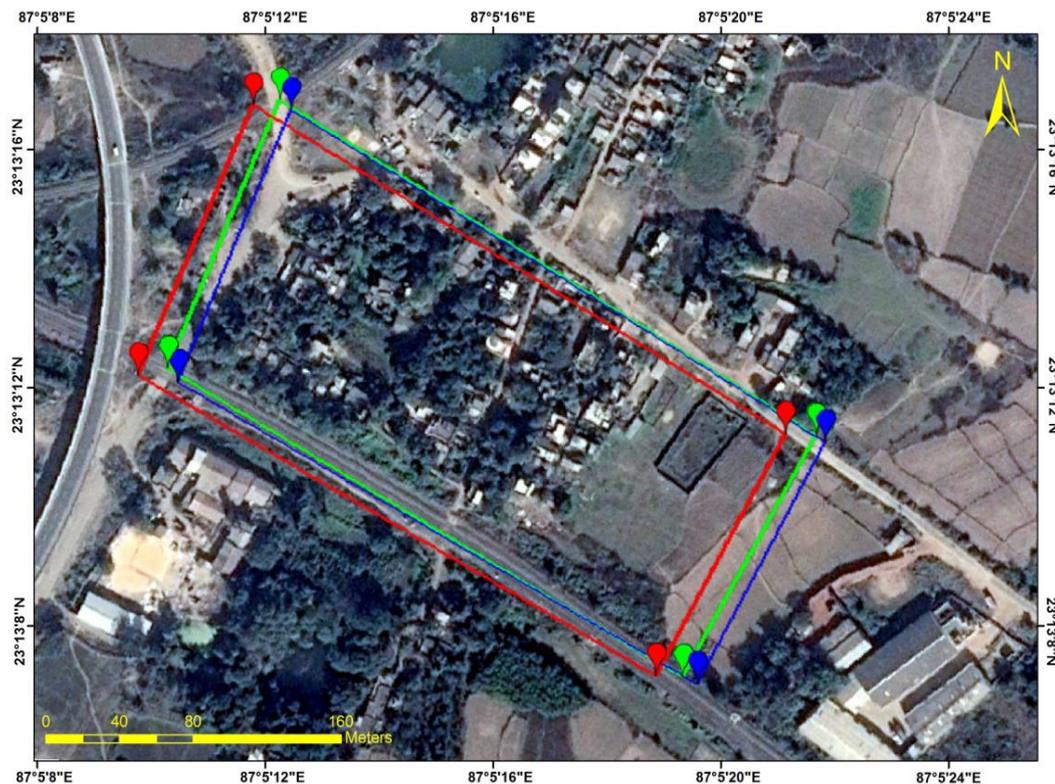
$\Delta\lambda$  is the difference in longitudes between two points.

R is radius of the earth i.e., 6371 KM.

d is distance between two points.

In order to apply the above mentioned mathematical formula, it is necessary to process the reference data as well as unrectified data. The V1 is considered as reference data, whereas V2 and V3 are taken as unrectified data in this study. The distance between corresponding points of V1 and V2 layers i.e., A-A', B-B', C-C' and D-D' are calculated by using Haversine formula and the distance values are listed in Table 1.

Similarly, the distance between corresponding points of V1 and V3 layers i.e., A-A<sub>0</sub>, B-B<sub>0</sub>, C-C<sub>0</sub> and D-D<sub>0</sub> are calculated by Equation



**Figure 4:** The three sets of data points as well as their corresponding vector boundaries superimposed on GE satellite imagery of 16<sup>th</sup> December, 2016 are found to be not congruent.

Between two points	Angular distance value	Angular distance in radian	Distance in meter
A-A'	$1.30916715 \times 10^{-16}$	$1.31143354 \times 10^{-6}$	8.35
B-B'	$1.588657817 \times 10^{-16}$	$1.44433458 \times 10^{-6}$	9.2
C-C'	$1.380868697 \times 10^{-16}$	$1.34656964 \times 10^{-6}$	8.58
D-D'	$6.91645766 \times 10^{-17}$	$9.53003486 \times 10^{-7}$	6.07
Average distance value			8.05

**Table 1:** The distance values between corresponding points i.e., A-A', B-B', C-C' and D-D' are calculated by using Haversine formula.

Between two points	Angular distance value	Angular distance in radian	Distance in meter
A-A <sub>0</sub>	$4.15536384 \times 10^{-16}$	$2.33591564 \times 10^{-6}$	14.88
B-B <sub>0</sub>	$5.04276970 \times 10^{-16}$	$2.57328089 \times 10^{-6}$	16.39
C-C <sub>0</sub>	$3.77595737 \times 10^{-16}$	$2.22672286 \times 10^{-6}$	14.18
D-D <sub>0</sub>	$3.77950696 \times 10^{-16}$	$2.22776924 \times 10^{-6}$	14.19
Average distance value			14.91

**Table 2:** The distance values between corresponding points i.e. A-A<sub>0</sub>, B-B<sub>0</sub>, C-C<sub>0</sub> and D-D<sub>0</sub> calculated by Haversine formula are shown above.

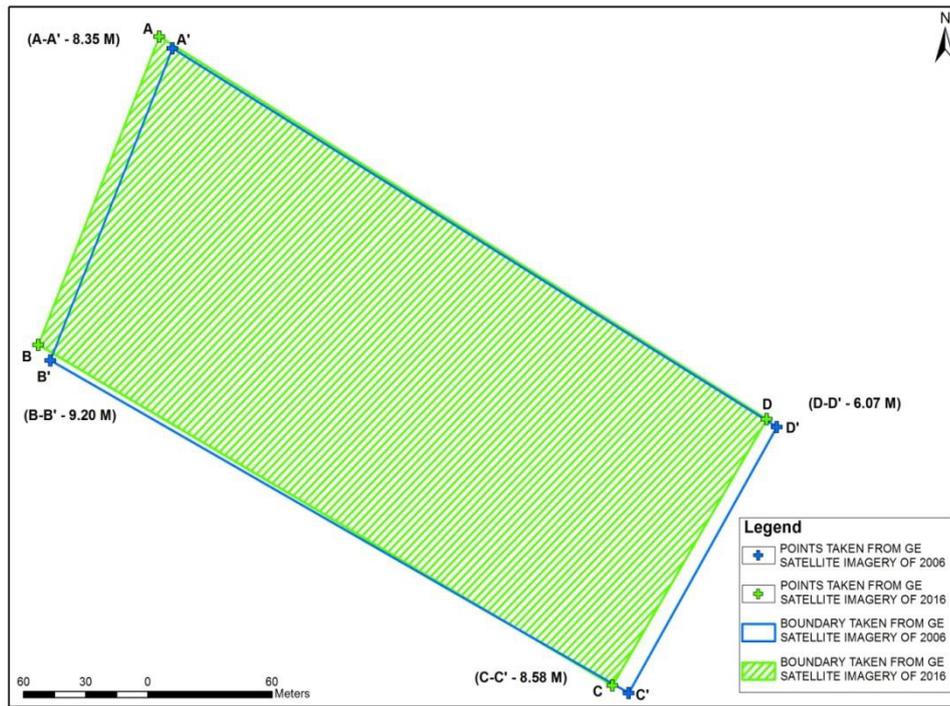
(1) and the distance values are shown in Table 2. The superimposition of two sets of vector layers namely V1-V2, V1-V3 and the distance values between their corresponding points i.e., A-A', B-B', C-C', D-D', A-A<sub>0</sub>, B-B<sub>0</sub>, C-C<sub>0</sub> and D-D<sub>0</sub> are depicted in Figures 5 and 6 respectively. The distance values between two corresponding points imply that the vector layers generated from multi-temporal satellite imagery of GE are shifted from one another.

In order to achieve our second objective, Lagrange form of interpolation polynomial formula is applied to minimize the distance value or to correct the mismatched data points in the study. This formula is used in constructing the new data point within the range of two discrete data points. Here, Lagrange form of interpolation polynomial

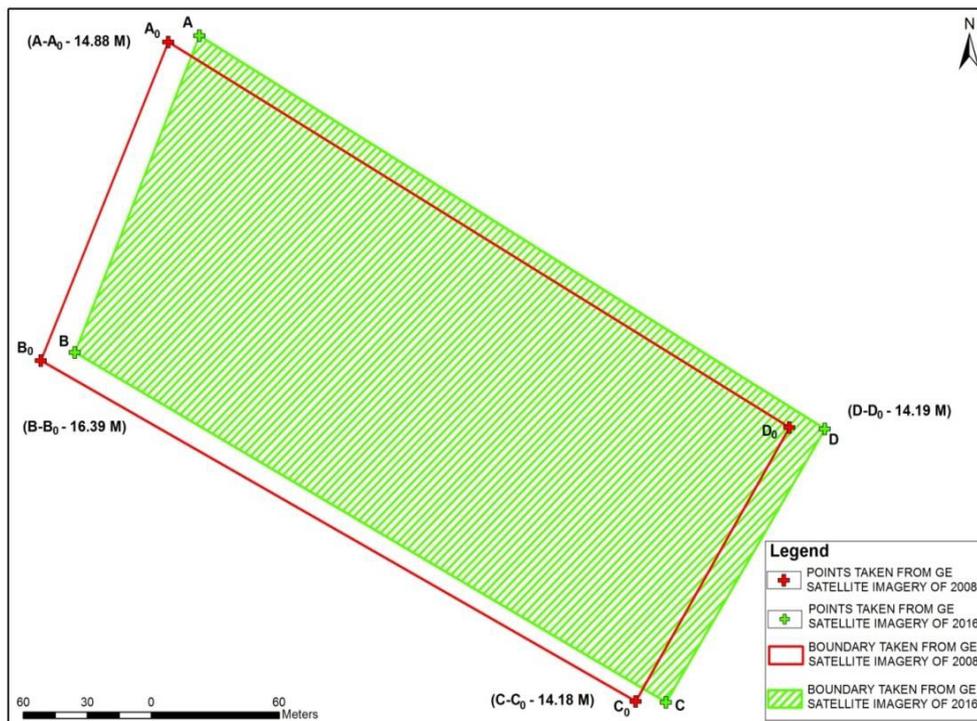
formula has been considered to fit the new data points with the reference data points by calculating the interpolated value of two corresponding data points. The reference data points namely A, B, C, D and the shifted two sets of data points namely A', B', C', D' and A<sub>0</sub>, B<sub>0</sub>, C<sub>0</sub>, D<sub>0</sub> are interpolated by Lagrange form of Interpolation Polynomial formula.

#### Lagrange form of interpolation polynomial formula

In the given set of discrete data points, such as  $(x_0, y_0), (x_1, y_1), \dots, (x_{n-1}, y_{n-1}), (x_n, y_n)$  the value of  $y$  at any other value of  $x$  can be found out by using a continuous function  $f(x)$  that represents the  $n+1$  data values with  $f(x)$  passing through the  $n+1$  points and it is known as Interpolation [8]. The points  $x_0, \dots, x_n$  are called Interpolation points and the points  $y_0, \dots, y_n$  are interpolated by the continuous function



**Figure 5:** The distance values between the shifted data points (A', B', C', D') and the reference data points (A, B, C, D) are calculated by Haversine formula.



**Figure 6:** The distance values between the shifted data points i.e., A<sub>0</sub>, B<sub>0</sub>, C<sub>0</sub>, D<sub>0</sub> and the reference data points i.e. A, B, C, D are calculated by Haversine formula.

$f(x)$ . The function, by which the data points are interpolated, called an Interpolant or the Interpolating Polynomial [9]. The Lagrange form of interpolation polynomial taken from [8] is illustrated as follows:-

$$P_n(x_i) = \sum_{j=0}^n f(x_j) \mathcal{L}_j^n(x_i), 0 \leq i \leq n. \quad (2)$$

$$\mathcal{L}_j^n(x_i) = \prod_{i \neq j} \frac{(x - x_i)}{(x_j - x_i)}, j = 0, \dots, n.$$

In order to obtain the Lagrange form of Interpolation Polynomial of degree one, the formula can be written as under:-

$$P_1(x) = \sum_{j=0}^1 f(x_j) \mathcal{L}_j^1(x), 0 \leq i \leq 1.$$

$$P_1(x) = f(x_0) \mathcal{L}_0^1(x) + f(x_1) \mathcal{L}_1^1(x), \text{ where } \mathcal{L}_0^1(x) = \frac{(x - x_1)}{(x_0 - x_1)}, \mathcal{L}_1^1(x) = \frac{(x - x_0)}{(x_1 - x_0)}$$

$$P_1(x) = f(x_0) \frac{(x - x_1)}{(x_0 - x_1)} + f(x_1) \frac{(x - x_0)}{(x_1 - x_0)}, P_1(x) = y_0 \frac{(x - x_1)}{(x_0 - x_1)} + y_1 \frac{(x - x_0)}{(x_1 - x_0)}$$

Where  $y_0, y_1$  and  $x_0, x_1$  are longitude and latitude values of the reference data points and  $x$  denotes latitude value of the shifted data points. The shifted data points i.e., A', B', C', D' and reference data points i.e., A, B, C, D are taken as the first two sets of data points and the calculated four interpolated values are given in Table 3. Similarly, the shifted data points ( $A_0, B_0, C_0, D_0$ ) and the reference data points (A, B, C, D) are taken as the second two sets of data points and the calculated other four interpolated values are mentioned in Table 4.

Between two points	Interpolated value
A-A'	87.08670028
B-B'	87.08630647
C-C'	87.08867057
D-D'	87.08941426

**Table 3:** Based on the shifted data points (A', B', C', D') and the reference data points (A, B, C, D), the interpolated values are calculated by Lagrange form of Interpolation Polynomial formula.

Between two points	Interpolated value
A- $A_0$	87.08670932
B- $B_0$	87.08625044
C- $C_0$	87.08869239
D- $D_0$	87.08935098

**Table 4:** Based on the shifted data points ( $A_0, B_0, C_0, D_0$ ) and the reference data points (A, B, C, D), the interpolated values are calculated by Lagrange form of Interpolation Polynomial formula.

Between two points	Angular distance value	Angular distance in radian	Distance in meter
A-E'	$6.261800053 \times 10^{-17}$	$9.06780616 \times 10^{-7}$	5.78
B-F'	$3.892632154 \times 10^{-16}$	$2.26086333 \times 10^{-6}$	14.40
C-G'	$3.242981552 \times 10^{-17}$	$6.52566638 \times 10^{-7}$	4.15
D-H'	$8.898642631 \times 10^{-17}$	$1.08097216 \times 10^{-6}$	6.88
Average distance value			7.80

**Table 5:** The distance values between the new data points namely E', F', G', H' and the reference data points namely A, B, C, D are measured by Haversine formula.

Between two points	Angular distance value	Angular distance in radian	Distance in meter
A- $E_0$	$1.84133847 \times 10^{-17}$	$4.91721777 \times 10^{-7}$	3.13
B- $F_0$	$9.81374393 \times 10^{-17}$	$1.13519374 \times 10^{-6}$	7.23
C- $G_0$	$5.29249074 \times 10^{-19}$	$8.33647940 \times 10^{-8}$	0.53
D- $H_0$	$3.20400165 \times 10^{-18}$	$2.05115742 \times 10^{-7}$	1.30
Average distance value			3.04

**Table 6:** The distance values between the new data points namely  $E_0, F_0, G_0, H_0$  and the reference data points namely A, B, C, D are calculated by Haversine formula.

On the basis of interpolated values, the first set of new data points namely E', F', G', H' and on the other hand, the second set of the new data points namely  $E_0, F_0, G_0, H_0$  are created respectively. These two sets of new data points are found to be mismatched with the reference data points and the distance values between two corresponding points are mentioned in Tables 5 and 6. Similarly, the vector boundaries prepared from each set of new data points are observed to be shifted from the reference vector boundary. The shifted and reference vector boundary along with their data points are graphically represented in Figures 7 and 8. The outcome of The Lagrange form of the interpolation polynomial of order one shows that the distance values between the corresponding new sets of data points and the reference data points are not reduced as much as expected for the correction of data. In addition to this, it will be relevant to say that the Lagrange form of Interpolation Polynomial does not give us the desired result. Therefore, another attempt has been considered to minimize the distance value by use of any appropriate mathematical function. Hence, a linear transformations method is used for the correction of data, known as Affine transformation.

### Affine transformation

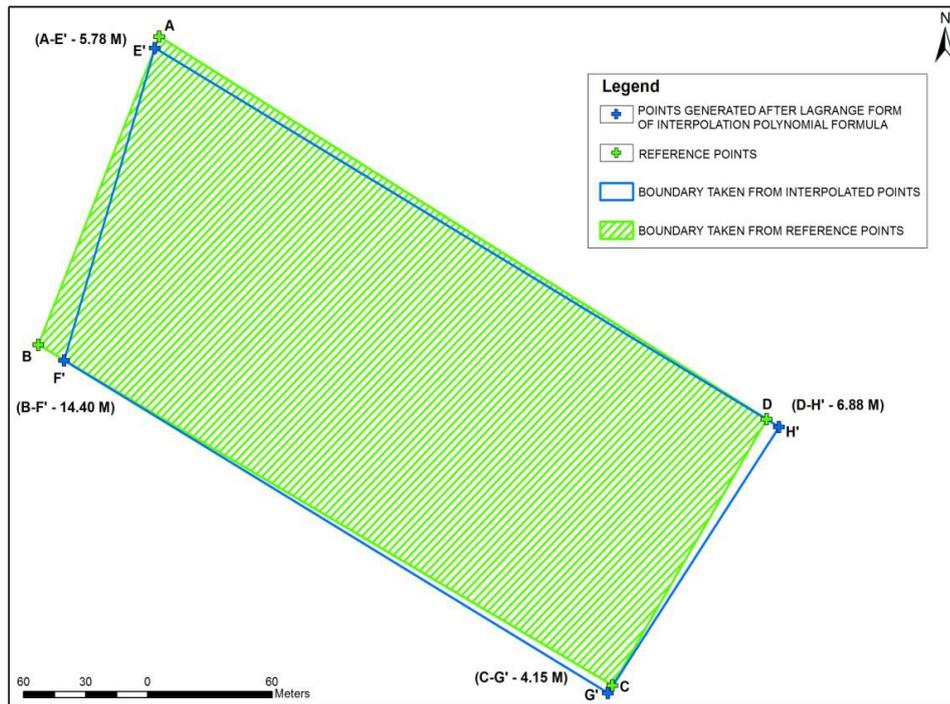
Affine transformation is a combination of translation, rotation and scaling, in which the coordinate points, the angle of axes and the size of coordinate space are changed from one Euclidean coordinate space to a new Euclidean coordinate space [10,11]. The translation, rotation and scaling are discussed in sequence as follows:

A translation can be applied in an Affine transformation to move the coordinate system from one Euclidean vector space to other. A translation is not a linear transformation but a function in which the shifted coordinate points are moved to the origin of the coordinate system in a particular direction.

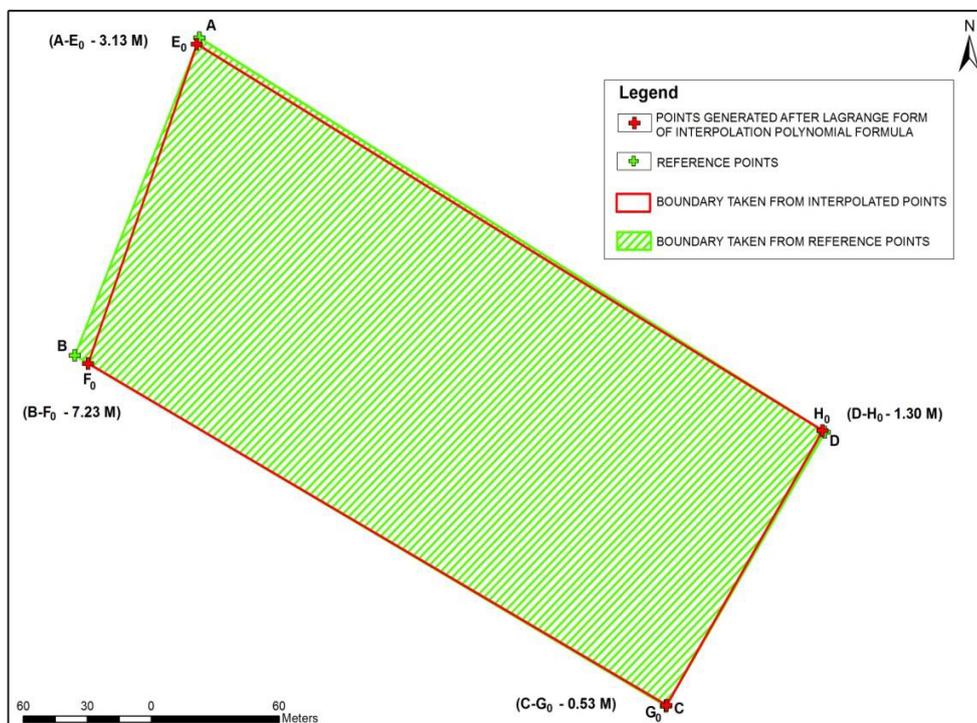
$$\text{The translation matrix } T = \begin{bmatrix} 1 & 0 & -X_0 \\ 0 & 1 & -Y_0 \\ 0 & 0 & 1 \end{bmatrix}$$

A rotation allows to rotate and to reposition the entire Euclidean coordinate space around a fixed point by an angle of  $\theta$ . The point about which the axes of Euclidean coordinate space is rotated either clock wise or counter clock wise.

$$\text{The rotation matrix } R = \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



**Figure 7:** The calculated distance values between the first set of new data points (E', F', G', H') and the reference data points (A, B, C, D) imply that the shifted and reference vector boundaries are not matched with each other.



**Figure 8:** The calculated distance values between the second set of new data points (E<sub>0</sub>, F<sub>0</sub>, G<sub>0</sub>, H<sub>0</sub>) and the reference data points (A, B, C, D) indicate that the shifted and reference vector boundaries are mismatched with each other.

A scaling transformation is a linear transformation in which the size of Euclidean coordinate space is found to be changed by a scaling factor. Since the value of scaling factor is either greater than one or less than one, it determines a non-uniform scaling. In order to obtain a uniform scaling in any Euclidean coordinate space, the scaling transformation is applied in an Affine transformation.

$$\text{The scaling matrix } S = \begin{bmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Therefore, the equation of Affine transformation taken from Clarke [10] can be expressed as follows:

$$X' = X_0 + S_x \cos \theta (X - X_0) - S_x \sin \theta (Y - Y_0) \quad (3)$$

$$Y' = Y_0 + S_y \sin \theta (X - X_0) + S_y \cos \theta (Y - Y_0)$$

The upper mentioned formula can be illustrated from Clarke [10] as under.

$$\begin{bmatrix} X & Y & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -X_0 \\ 0 & 1 & -Y_0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} X - X_0 & Y - Y_0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} X - X_0 & Y - Y_0 & 1 \end{bmatrix} \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \cos \theta (X - X_0) - \sin \theta (Y - Y_0) & \sin \theta (X - X_0) + \cos \theta (Y - Y_0) & 1 \end{bmatrix}$$

$$\begin{bmatrix} \cos \theta (X - X_0) - \sin \theta (Y - Y_0) & \sin \theta (X - X_0) + \cos \theta (Y - Y_0) & 1 \end{bmatrix} \begin{bmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} S_x [\cos \theta (X - X_0) - \sin \theta (Y - Y_0)] & S_y [\sin \theta (X - X_0) + \cos \theta (Y - Y_0)] & 1 \end{bmatrix}$$

Where  $X'$ ,  $Y'$  are new points in new coordinate system after the process of affine transformation.  $X_0$ ,  $Y_0$  are the shifted points in old coordinate system and  $X$ ,  $Y$  are the reference points in old coordinate system. The Affine transformation formula mentioned above has been applied in the first two sets of data points i.e., A', B', C', D' and A, B, C, D. The matrices of Translation (T), Rotation (R) and Scaling (S) are as given below.

The transformation values are based on A' and A coordinate points shown in matrix form.

$$T = \begin{bmatrix} 1 & 0 & 0.000058 \\ 0 & 1 & -0.000048 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} 0.999941023 & 0.010860485 & 0 \\ -0.010860485 & 0.999941023 & 0 \\ 0 & 0 & 1 \end{bmatrix}, S = \begin{bmatrix} 0.996128845 & 0 & 0 \\ 0 & 1.001771843 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The transformation values are based on B' and B coordinate points shown in matrix form.

$$T = \begin{bmatrix} 1 & 0 & 0.000052 \\ 0 & 1 & -0.000064 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} 0.999048574 & 0.043611298 & 0 \\ -0.043611298 & 0.999048574 & 0 \\ 0 & 0 & 1 \end{bmatrix}, S = \begin{bmatrix} 0.996128845 & 0 & 0 \\ 0 & 1.001771843 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The transformation values are based on C' and C coordinate points shown in matrix form.

$$T = \begin{bmatrix} 1 & 0 & 0.000070 \\ 0 & 1 & -0.000032 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} 0.999754426 & 0.022160473 & 0 \\ -0.022160473 & 0.999754426 & 0 \\ 0 & 0 & 1 \end{bmatrix}, S = \begin{bmatrix} 0.996128845 & 0 & 0 \\ 0 & 1.001771843 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The transformation values are based on D' and D coordinate points shown in matrix form.

$$T = \begin{bmatrix} 1 & 0 & 0.000044 \\ 0 & 1 & -0.000032 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} 0.999852065 & 0.017200195 & 0 \\ -0.017200195 & 0.999852065 & 0 \\ 0 & 0 & 1 \end{bmatrix}, S = \begin{bmatrix} 0.996128845 & 0 & 0 \\ 0 & 1.001771843 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The four new coordinate points obtained from the above formula are named as I', J', K' and L' in this study. The distance values between the new coordinate points (I', J', K', L') and reference coordinate points (A, B, C, D) are calculated by Haversine formula and given in Table 7. Similarly, the second two sets of data points i.e., A<sub>0</sub>, B<sub>0</sub>, C<sub>0</sub>, D<sub>0</sub> and A, B, C, D are calculated by Affine transformation formula and the matrices of Translation (T), Rotation (R) and Scaling (S) are as under:

The transformation values are based on A<sub>0</sub> and A coordinate points shown in matrix form.

$$T = \begin{bmatrix} 1 & 0 & -0.000131 \\ 0 & 1 & 0.000026 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} 0.997811234 & 0.066126695 & 0 \\ -0.066126695 & 0.997811234 & 0 \\ 0 & 0 & 1 \end{bmatrix}, S = \begin{bmatrix} 0.993422942 & 0 & 0 \\ 0 & 1.000739311 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The transformation values are based on B<sub>0</sub> and B coordinate points shown in matrix form.

$$T = \begin{bmatrix} 1 & 0 & 0.000144 \\ 0 & 1 & 0.000032 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} 0.999616864 & 0.027678937 & 0 \\ -0.027678937 & 0.999616864 & 0 \\ 0 & 0 & 1 \end{bmatrix}, S = \begin{bmatrix} 0.993422942 & 0 & 0 \\ 0 & 1.000739311 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The transformation values are based on C<sub>0</sub> and C coordinate points shown in matrix form.

$$T = \begin{bmatrix} 1 & 0 & 0.000128 \\ 0 & 1 & -0.000004 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} 0.998001017 & 0.063197873 & 0 \\ -0.063197873 & 0.998001017 & 0 \\ 0 & 0 & 1 \end{bmatrix}, S = \begin{bmatrix} 0.993422942 & 0 & 0 \\ 0 & 1.000739311 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The transformation values are based on D<sub>0</sub> and D coordinate points shown in matrix form.

$$T = \begin{bmatrix} 1 & 0 & 0.000150 \\ 0 & 1 & -0.000006 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} 0.999964776 & 0.008393189826 & 0 \\ -0.008393189826 & 0.999964776 & 0 \\ 0 & 0 & 1 \end{bmatrix}, S = \begin{bmatrix} 0.993422942 & 0 & 0 \\ 0 & 1.000739311 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The four new coordinate points obtained from Equation (3) are named as I<sub>0</sub>, J<sub>0</sub>, K<sub>0</sub> and L<sub>0</sub>. The distance values between of the new coordinate points (I<sub>0</sub>, J<sub>0</sub>, K<sub>0</sub>, L<sub>0</sub>) and reference coordinate points (A, B, C, D) are calculated by Haversine formula and mentioned in Table 8. On the basis of two sets of new coordinate points, two separate vector

Between two points	Angular distance value	Angular distance in radian	Distance in meter
A-I'	$2.305706016 \times 10^{-20}$	$1.740021419 \times 10^{-8}$	0.11
B-J'	$2.566331315 \times 10^{-19}$	$5.805090434 \times 10^{-8}$	0.36
C-K'	$4.576867209 \times 10^{-20}$	$2.451527584 \times 10^{-8}$	0.15
D-L'	$2.474978437 \times 10^{-20}$	$1.802761762 \times 10^{-8}$	0.11
Average distance value			0.18

Table 7: The distance values between the new coordinate points (I', J', K', L') and reference coordinate points (A, B, C, D) are calculated by Haversine formula.

Between two points	Angular distance value	Angular distance in radian	Distance in meter
A-I <sub>0</sub>	$9.733606919 \times 10^{-19}$	$1.13050000 \times 10^{-7}$	0.72
B-J <sub>0</sub>	$4.058995077 \times 10^{-19}$	$7.30065608 \times 10^{-8}$	0.46
C-K <sub>0</sub>	$1.730606859 \times 10^{-18}$	$1.50748097 \times 10^{-7}$	0.96
D-L <sub>0</sub>	$7.383971245 \times 10^{-20}$	$3.11384955 \times 10^{-8}$	0.19
Average distance value			0.58

Table 8: The distance values between the new coordinate points (I<sub>0</sub>, J<sub>0</sub>, K<sub>0</sub>, L<sub>0</sub>) and reference coordinate points (A, B, C, D) are calculated by Haversine formula.

boundaries are created for further observation of the study. The vector boundary generated from new coordinate points (I', J', K', L') is superimposed on the reference vector boundary as shown in Figure 9. In the same way, the vector boundary created by new coordinate points (I<sub>0</sub>, J<sub>0</sub>, K<sub>0</sub>, L<sub>0</sub>) is overlaid on the reference boundary as shown in Figure 10.

### Results and Discussion

The outcome of this research work shown in Table 7 indicates that Affine transformation method has been able to minimize the distance values between the corresponding new coordinate points (I', J', K', L') and reference coordinate points (A, B, C, D) in the range of 0.11

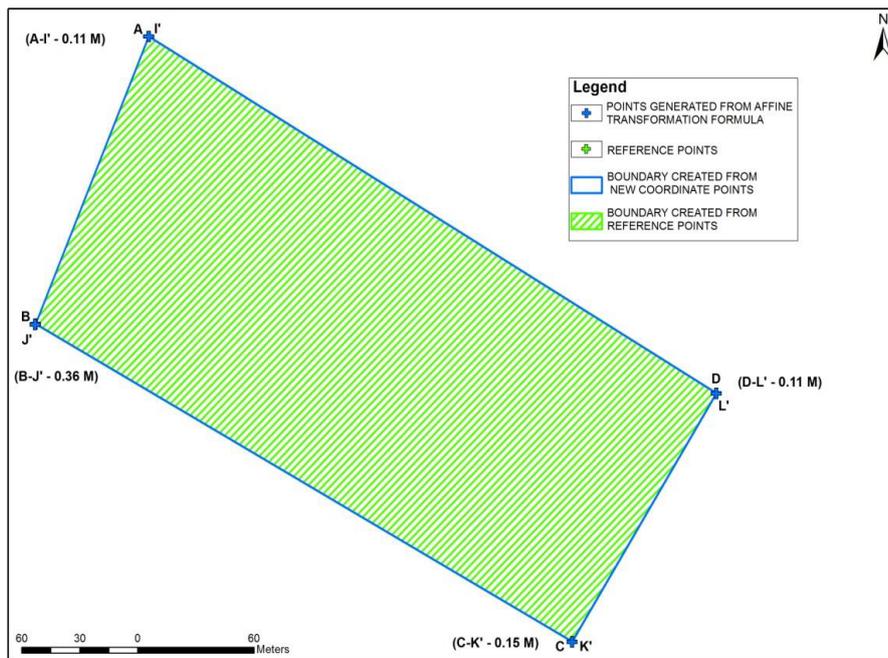


Figure 9: The distance values between the new coordinate points (I', J', K', L') and the reference coordinate points (A, B, C, D) point out that the shifted and reference vector boundaries are almost found to be congruent with each other.

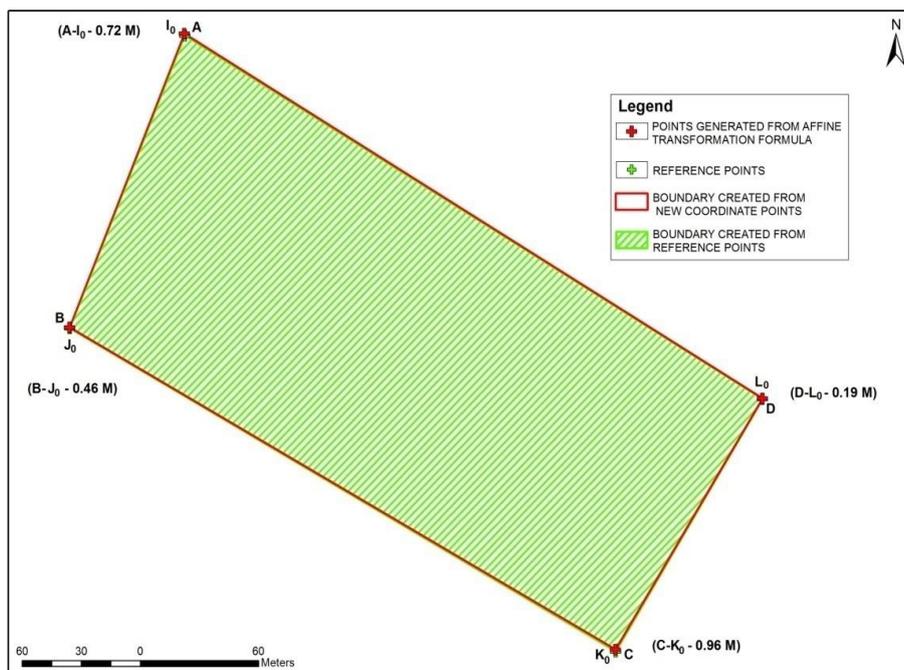


Figure 10: The distance values between the new coordinate points (I<sub>0</sub>, J<sub>0</sub>, K<sub>0</sub>, L<sub>0</sub>) and the reference coordinate points (A, B, C, D) show that the shifted and reference vector boundaries are almost found to be fitting with each other.

to 0.36 m. In addition to this, the average distance value mentioned above in Table 7 is found to be 0.18 m, whereas the actual average distance value calculated by Haversine formula is found to be 8.05 m as shown in Table 1. On the other hand, after the process of Lagrange form of Interpolation Polynomial method between the corresponding new data points (E', F', G', H') and reference data points (A, B, C, D), Table 5 shows that the average distance comes out as 7.80 m, which can be close to the actual average distance value i.e., 8.05 m. Similarly, after applying the formula of Affine transformation, the distance values between the corresponding new coordinate points ( $I_0, J_0, K_0, L_0$ ) and reference coordinate points (A, B, C, D) vary from 0.19 to 0.96 m as indicated in Table 8. Moreover, the average distance value is observed to be 0.58 m. Prior to using Affine transformation formula, an attempt has been initiated to minimize the actual average distance value i.e., 14.91 m and this value has been reduced from 14.91 to 3.04 m by applying Lagrange form of Interpolation Polynomial formula as mentioned in Table 6. However, Tables 5 and 6 represent that Lagrange form of Interpolation Polynomial formula can't provide more accurate result in terms of minimizing the distance values between the shifted and reference data points. On the other hand, it is further observed that the new coordinate points generated by composite transform functions namely Translation(T), Rotation(R) and Scaling(S) of Affine transformation formula are almost matched with the corresponding reference points having negligible distance value as pointed out in Tables 7 and 8. Eventually, the distance values obtained from Lagrange form of Interpolation Polynomial formula and Affine transformation formula clearly indicate that Affine transformation formula is one of the most satisfying method to reduce the average distance value and to rectify the geometric distortion of vector data in comparing with Lagrange form of Interpolation Polynomial formula.

## Conclusion

The distance values between the corresponding points showing the vector data prepared from multi-temporal satellite imagery of Google Earth are shifted from one another that has been clearly analyzed by using the above mentioned formulas and at the same time, the distance values have been attempted to minimize as much as possible using Lagrange form of Interpolation Polynomial and Affine transformation formula. The distance values between two sets of corresponding points indicate the difference of calculated distance values in m, which further supports that the vector data generated from multi-temporal satellite data of GE are shifted from one another.

The findings above imply to the researcher or educator, who are more interested working with GE imagery in terms of 'Change Detection' study on any particular place of the earth. Any kind of 'Change Detection' study either the drastic changes of vast geographical area by the effect of natural disaster like earthquake, flood, forest-fire or moderate changes of any small area by the influence of anthropogenic activities like mining, urbanization, deforestation etc. can be interpreted appropriately by GE satellite imagery. However, prior to using the vector data taken from different period of GE satellite images for the purpose of different aspect of study, the geometric correction of data is mandated in order to have accurate experimental research work, otherwise the geographical position of vector data could be shifting as well as the area of vector data might be different, as has been illustrated mathematically.

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