SEMI-AUTOMATIC GENERATION OF MOSAIC FROM OVERLAPPING IMAGES USING MATLAB

O. G. Ajayi[1+]; J. O. Odumosu[2]; C. V. Okorocha[3]; I. C. Nzelibe[4], H. A. Ahmadu[5], S. Bawa[6]
[1,2]Department of Surveying and Geoinformatics, Federal University of Technology, Minna

[3,4,5,6] Department of Surveying and Geoinformatics, University of Lagos, Nigeria.

Corresponding Author[1+]
Postal Address: Department of Surveying and Geoinformatics,
Federal University of Technology, Minna
P. M. B. 65, Minna, Niger State, NIGERUA

ABSTRACT: *Construction of Mosaic from overlapping images is a crucial issue in change detection and other applications. Image registration which seek to fuse images acquired in patches together is a laborious and computationally intensive task. This study presents a user-assisted (Geometric based) image registration algorithm using the Image Processing toolbox of MATLAB. Orthogonal Transformation, Affine and Projective Transformation functions were applied and Root Mean Square Deviation was used for the evaluation of mismatch (errors). The results proved that Registration based on Projective Transformation function was of better accuracy than the Affine Transformation function while Orthogonal Transformation based registration gave the poorest result.*

KEYWORDS: Image Registration, Mosaic, Transformation functions, Affine, Orthogonal, RMSD, Projective, Overlapping images.

INTRODUCTION

Registration is the determination of a geometrical transformation that aligns points in one view of an object with corresponding points in another view of that object or another object. It is the process of superimposing two images and transforming one of them to find the best transform to make them match (Campbel, 1987, Jensen, 1996). Many applications in remote sensing rely on image registration. These include three-dimensional mapping of the land and sea surface, identifying and mapping different types of land use, measuring and analyzing natural and agricultural vegetation, matching stereo images to recover shape for autonomous navigation, and aligning images from different medical modalities for diagnosis. With the dramatic increase in data volumes and types of sensors, image registration became also crucial for content-based retrieval of remote sensing data and image data from large data repositories. Image registration is to determine the transformation between a newly sensed image, called input image, and a reference image. Broad range of techniques for image registration has been categorized in

(Brown, 1992). The complexity of the search and similarity measurement in image registration could be computationally intensive. Hence the need for an automated Image registration model.

Generally, Image registration is in two parts. (i) Image to Object registration and (ii) Image to image registration. The images to object registration also includes registration of an image onto an existing map. For this, control points are usually required. Image to image registration is don't to overlay one image on another for comparison or change detection. It could also be to join one image to another as in the production of mosaic. This could also be called edge-matching.

Registration Problem

The problem of image registration is as follows: given two different representations of the same object, find a transformation which, when applied to one image, will align (or register) points in that image with corresponding points in the other. By using appropriate computational algorithms, a mapping (transformation) between two images spatially and with respect to intensity can be found to produce a new informative image which has functional and structural information. Mathematically, If we have two 2D datasets (images) of a given size denoted by A_0 and A_1 where $A_0\ (x,y)$ and $A_1\ (x,y)$ each map to their respective intensity values, then mapping between these two images can be expressed as:

$$A_1(x,y) = g(A_0(f(x,y))) + e(x,y) \qquad [1.0a]$$

Approximately, $A_1(x,y) = g(A_0(f(x,y)))$ [1.0b]

when $e(x,y)=0$ Where $e(x,y)$ is an error vector (residual) and is said to be zero when we have a perfect registration, f is a 2D Spatial coordinate transformation $i.e\ (x,y) = f(x,y)$ and g is a 1D intensity or radiometric transformation. Registration problem is thus the task involved in finding the optimal spatial and intensity transformation f and g although the spatial transformation is generally the key to the problem.

1.2 Transformation Functions

The type of spatial or geometric transformation needed to properly overlay the input and reference image is one of the most fundamental and difficult tasks in any image registration technique (Rami Al-Ruzouq. 2004). The establishment of the transformation function that mathematically describes the mapping between imagery in question is a major issue in image registration. In other words, given a pair of images, reference and input images, the transformation function attempts properly to overlay these images. The functions, used to align two images, may be global or local. A global transformation is given by a single set of equations, which optimally registers all the pixels in the two images. Local transformations map the images depending on the spatial location; this results in several sets of equations for one map. Local transformations are usually more accurate but also more computationally demanding (Fonseca and Manjunath, 1996).

ISSN 2053-5783(Print), ISSN 2053-5791(online)

To overcome the problem of geometric distortions, several types of transformation functions have been considered and three of them were used for this research. Starting with the two dimensional conformal transformation, also known as *2-D similarity or Orthogonal Transformation*. This transformation is sufficient to match two images with rigid-body distortion (Brown, 1992) where the true shape is retained. This is a four-parameter transformation that includes two translations in x- and y-directions, one scale and one rotation. At least two tie points are required to solve for the parameters of the 2-D similarity transformation
Mathematically, orthogonal transformation is as given in equation (2.0a and 2.b):

$$x = au + bv + c \qquad [2.0a]$$

$$y = -bu + av + d \qquad [2.0b]$$

Equations (2.0a) and (2.0b) can be put in the following matrix notation (Equation 2.0c):

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ -b & a \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} + \begin{bmatrix} c \\ d \end{bmatrix} \qquad [2.0c]$$

$\propto = rotation\ angle, T_x = Translation\ in\ x\ axis\ and\ T_y = Translation\ on\ y\ axis$

Where: $a = \cos\alpha$, $b = \sin\alpha$, $c = T_x$, $d = T_y$

The Affine is a six (6) parameter transformation with the following unknown parameters: a, b, c, d, e, f. Each transformation requires a minimum number of reference points (3 for affine, 6 for second order and 9 for third order polynomials). If more points are selected, the residuals and the derived Root Mean Square error (RMSE) or Sigma may be used to obtain the best estimates.

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \qquad [3.0]$$

Where: $\begin{bmatrix} a & b \\ c & d \end{bmatrix}$ are Scalar Quantities, $\begin{bmatrix} e \\ f \end{bmatrix}$ are Translation Parameters.

It modifies the orthogonal type by using different scale factors in the x and y directions. Affine Transformation corrects for shrinkage by means of scale factor, applies the translation to the shift of the origin and also performs rotation through angle θ (plus a small angular correction for non-orthogonality to orient the axes in the u, v photo system). Unlike orthogonal projection, affine projection allows oblique projection to an image plane (C. Stamatopoulos and C. S. Fraser, 2011).

The relational/Projective Transformation exactly describes a deformation of a flat scene photographed by a pin-hole camera the optical axis of which is not perpendicular to the scene (Barbara Zitova and Jan Flusser, 2003). It is an eight parameter transformation, which enables the analytical computation of the u, v coordinates of the points after they have been projected into a plane from another non- parallel plane and can be expressed by the operator;

$\phi\begin{bmatrix} a, b, c, d \\ e, f, g, h \end{bmatrix}$ and can be written as (Equation 4.0):

$$\begin{bmatrix} x \\ y \end{bmatrix} = \frac{1}{t}\begin{bmatrix} a & b \\ d & e \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} + \frac{1}{t}\begin{bmatrix} c \\ f \end{bmatrix} \qquad [4.0]$$

Where $t = gx + hy + 1$

$$x = \frac{ax + by + 1}{gx + hy + 1} \quad \text{and} \quad y = \frac{dx + cy + 1}{gx + hy + 1} \qquad [4.1]$$

METHODOLOGY

Semi-Automatic Geometric (Control Points) Registration is a type of image registration in which the user is expected to carry out on-screen selection of conjugate points (Corresponding Points visible on the reference Image and the input image) in order to register the two images together. The flow chart for the Geometric registration which shows the step by step procedure of carrying out a geometric registration is as summarized in Figure 1.0:

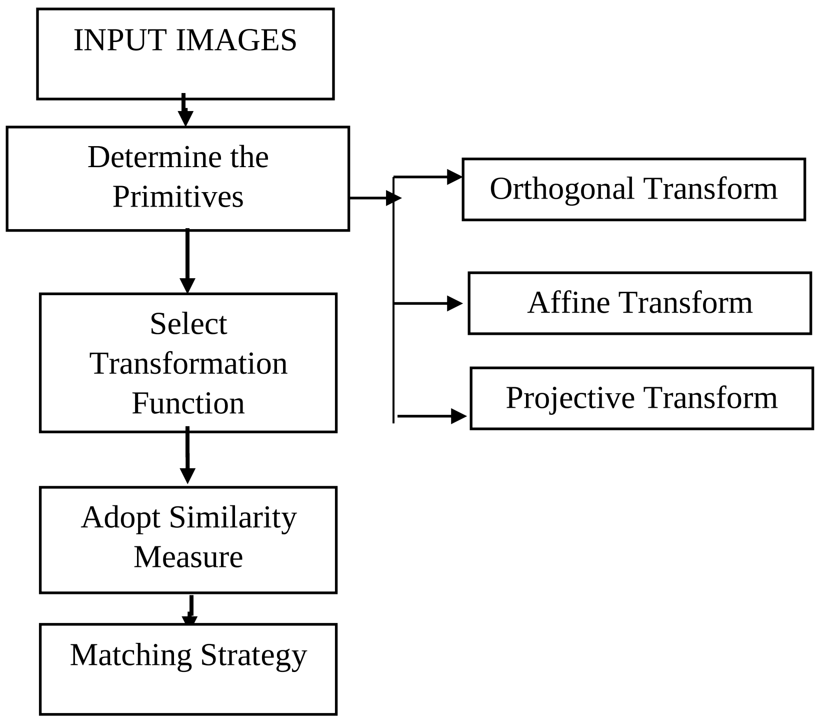

Figure 1.0: Flowchart of Geometric Registration

The steps highlighted in Figure 1.0 can be further elucidated as below:
Input Images: The developed program accepts images in different format as supported by the MATLAB environment. Some of this image formats include: JPEG, BMP, PNG, HDF, PCX, TIFF, XWB, etc. The model calls for the images to be registered and the Reference and Moving Images were fed into the algorithm.

ISSN 2053-5783(Print), ISSN 2053-5791(online)

Determination Of Primitives: Primitives are feature types to be used as conjugate features for registration this could be Points, lines Area, etc. For the sake of experimenting of this Model, Point Primitives were adopted, hence, conjugate Points were used for the Geometric registration of the two overlapping images. The number of points to be used (picked by the user) is thus a function of the transformation model preferred. i.e.: Orthogonal (2 Conjugate Pairs), Affine (3 Conjugate Pairs) and Projective Transformation (4 Conjugate Pairs).Selection Of Transformation Function: Transformation function mathematically relates the images to be registered. Three transformation Functions (Orthogonal, Affine and Projective Transformation functions) were used in the construction of this model.
Similarity Measure: This is to ensure the correspondence of the conjugate points selected.
Matching Strategy: This is the controlling framework that utilizes the Primitives, the Similarity Measure and the transformation function to solve the registration problem.

The step by step procedure of carrying out a semi-automatic geometric registration using our Model can be diagrammatically displayed as shown Figure 2.0.

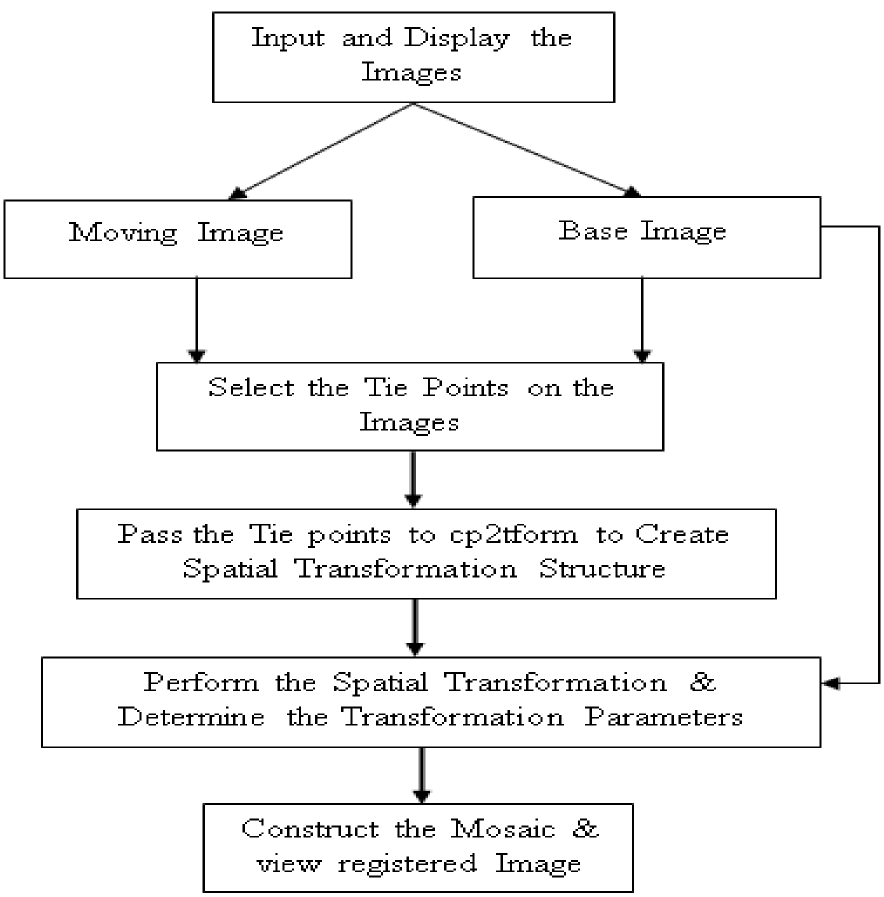

Figure 2.0: Flowchart showing the step by step procedure of carrying out a geometric (control point based) registration.

ISSN 2053-5783(Print), ISSN 2053-5791(online)

BUILDING A GRAPHIC USER INTERPHASE

For presentable packaging and to ensure interaction between the Model and the user, a simple and user-friendly Graphic User Interphase (GUI) was constructed and designed to harmonize all the written scripts (Program codes). The GUIDE builder within the MATLAB environment was used for the GUI design.

RESULTS AND ANALYSIS (MODEL EXPERIMENTATION)

The results obtained from the developed model for geometric based registration using three transformation models are as shown in the following subsections.
3.1 The Graphical User Interphase of the Model
Figure 3.0 shows the screen shot of the graphical user interphase developed for the model to aid user interaction with the model and for easy manipulation.

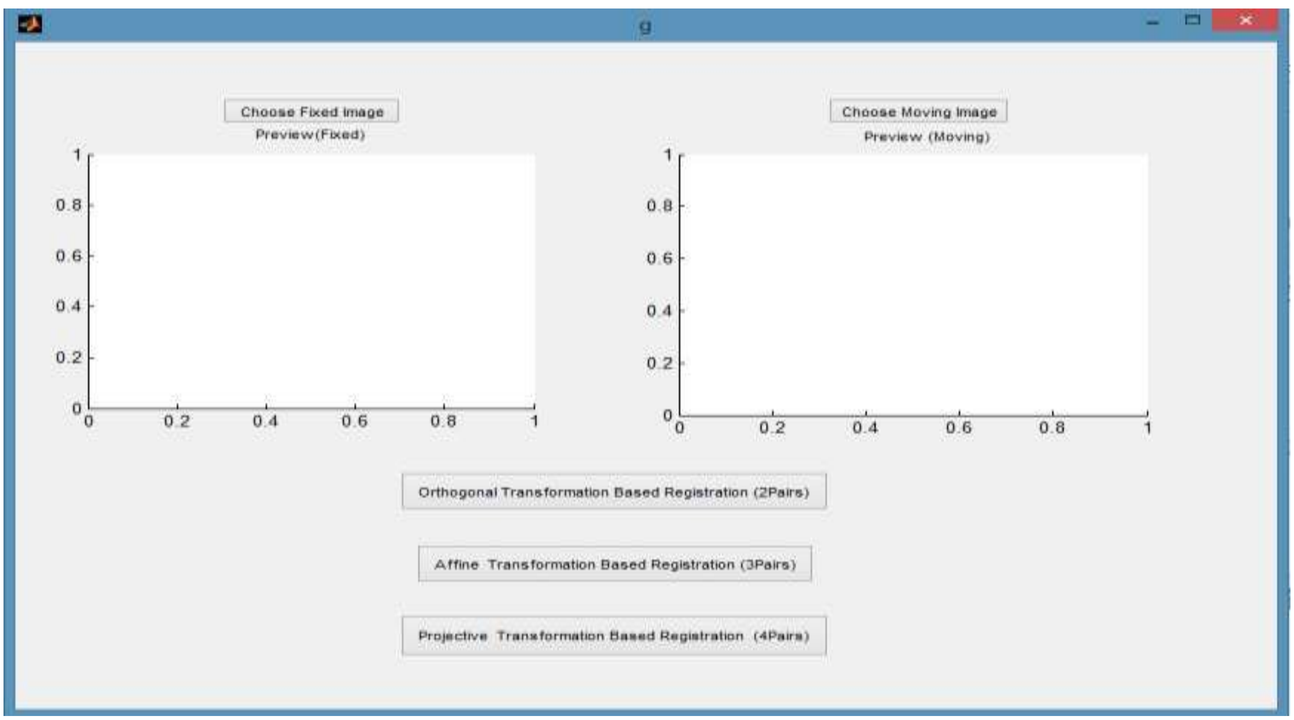

Figure 3.0: The Graphical User Interphase of the model

MODEL EXPERIMENTATION

The images used for the model experimentation are images showing aerial view of part of the University of Lagos, Akoka- Campus, Lagos Nigeria. They were extracted from Google Earth

ISSN 2053-5783(Print), ISSN 2053-5791(online)

Pro; a real time online images provider. The Images to be registered herein shown in Figure 4.0a&b.

Figure 4.0a: Showing an Image of part of UNILAG Campus (The Base Image)

Figure 4.0b: Showing an Image of part of UNILAG Campus (The Moving Image)

Using Orthogonal Transformation

In order to register these two images using the Semi-Automatic Registration model, the two images were launched into the model environment and conjugate points were selected on both the Base image (Left) and the Moving Image (Right) as shown in Figure 5.0a.

ISSN 2053-5783(Print), ISSN 2053-5791(online)

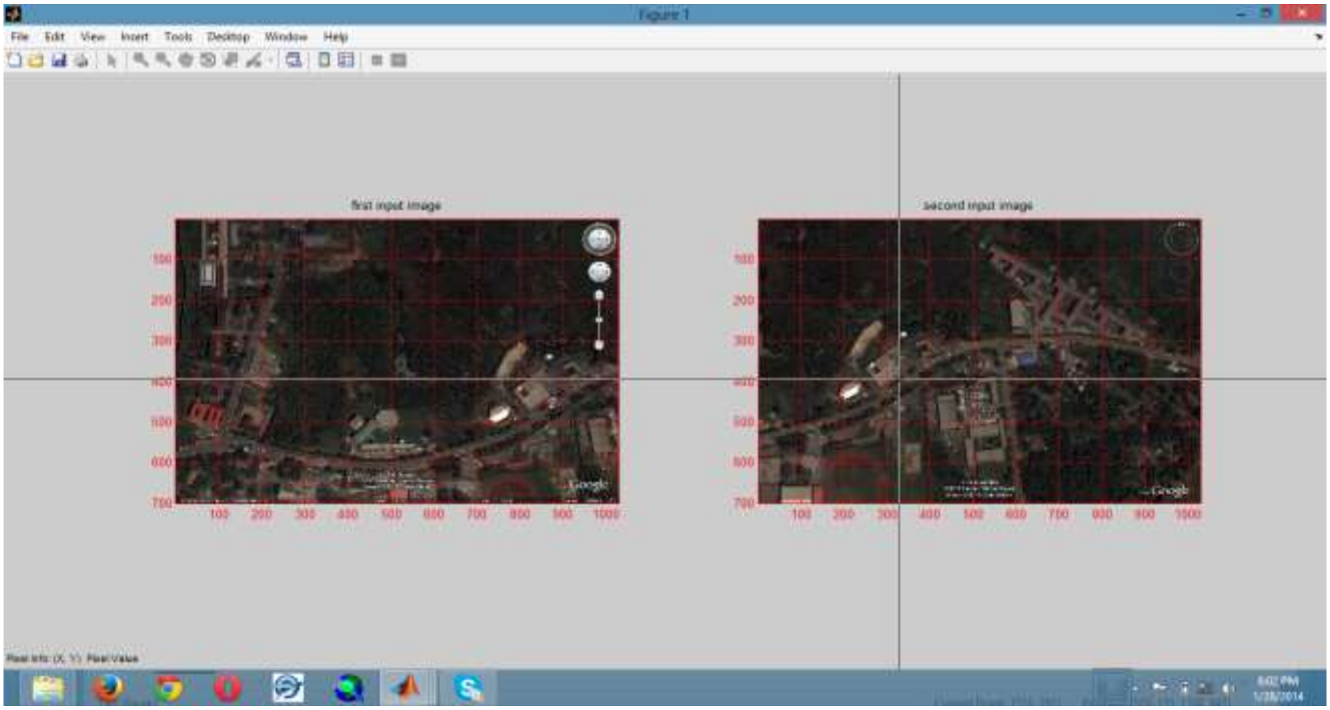

Figure 5.0a Showing the Process of Selecting Conjugate Points on both the Base (left) Moving and Moving Image

For there to be a successful registration of the two images, the model automatically computes the Transformation matrix used for the registration. Table 1.0 presents the coordinates of the conjugate points on both Base and Moving Image. These coordinates were used for the transformation matrix computation and the Root Mean square error was also computed.

	Base Image		Moving Image	
Conjugate Points Selected	Eastings Coordinates	Northings Coordinates	Eastings Coordinates	Northings Coordinates
1	726.106	491.5707	189.9417	435.4702
2	850.4158	479.0000	311.1287	422.9336

Table 1.0: Table showing the Coordinates of the Conjugate Points selected for the registration.

The Computed Transformation Matrix and RMSE for Orthogonal Transformation based registration are:

ISSN 2053-5783(Print), ISSN 2053-5791(online)

$$Z = \begin{bmatrix} 189.9417 & 435.4702 & 1.0000 & 0.0000 \\ 311.1287 & 422.9336 & 1.0000 & 0.0000 \\ 435.4702 & -189.9417 & 0.0000 & 1.0000 \\ 422.9336 & -311.1287 & 0.0000 & 1.0000 \end{bmatrix}, x_p = \begin{bmatrix} 726.1060 \\ 850.4158 \\ 491.5707 \\ 479.0000 \end{bmatrix},$$

$$T = \begin{bmatrix} 1.0255 & -0.0024 & 532.3435 \\ 0.0024 & 1.0255 & 44.5373 \\ 0.0000 & 0.0000 & 1.0000 \end{bmatrix}$$, Parameter Vector (t): a = 1.0255, b=-0.0024, Tx = 532.3435, Ty=44.5373. RMSE = 15.3389m

The result of the registration using orthogonal transformation function is shown in Figure 5.0b.

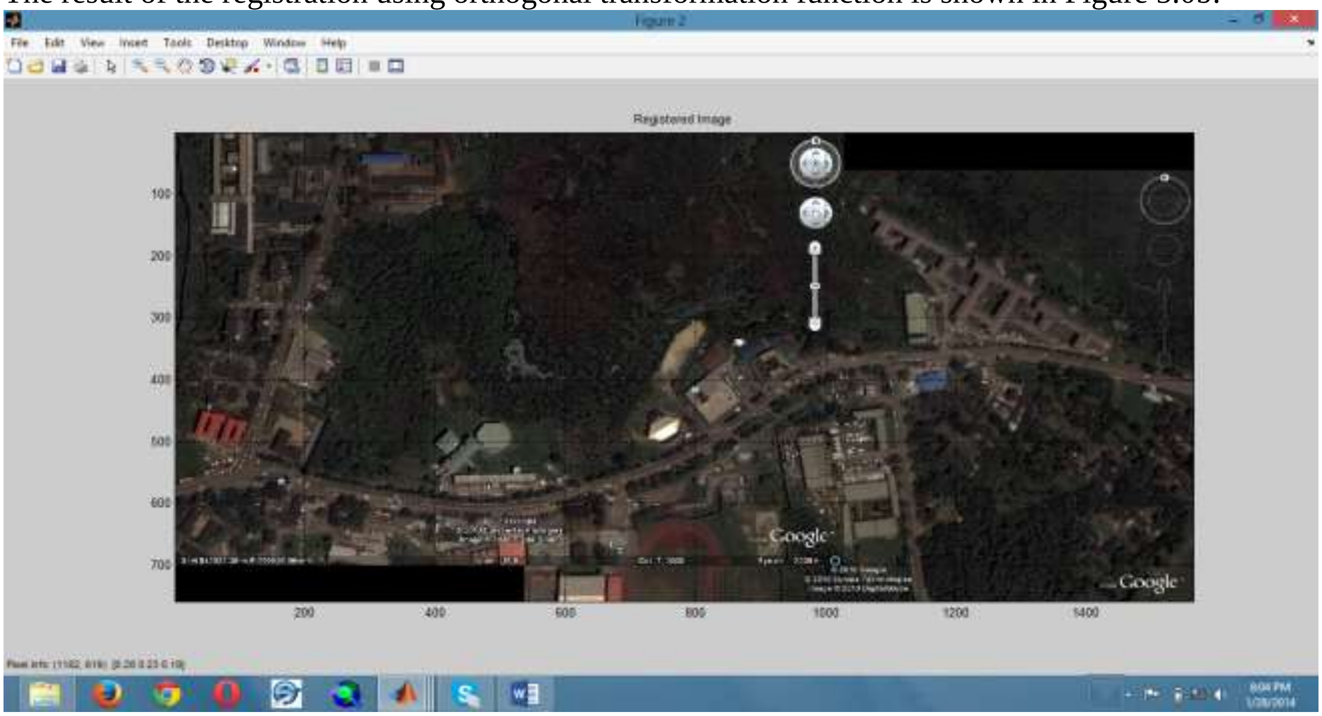

Figure 5.0b: Showing the Result obtained (registered image) using orthogonal transformation.

These same procedure was implemented by the Model in registering the images using the Affine and Projective transformation functions and the results obtained are herein presented in Figures 6.0a - 6.0b

ISSN 2053-5783(Print), ISSN 2053-5791(online)

Using Affine Transformation

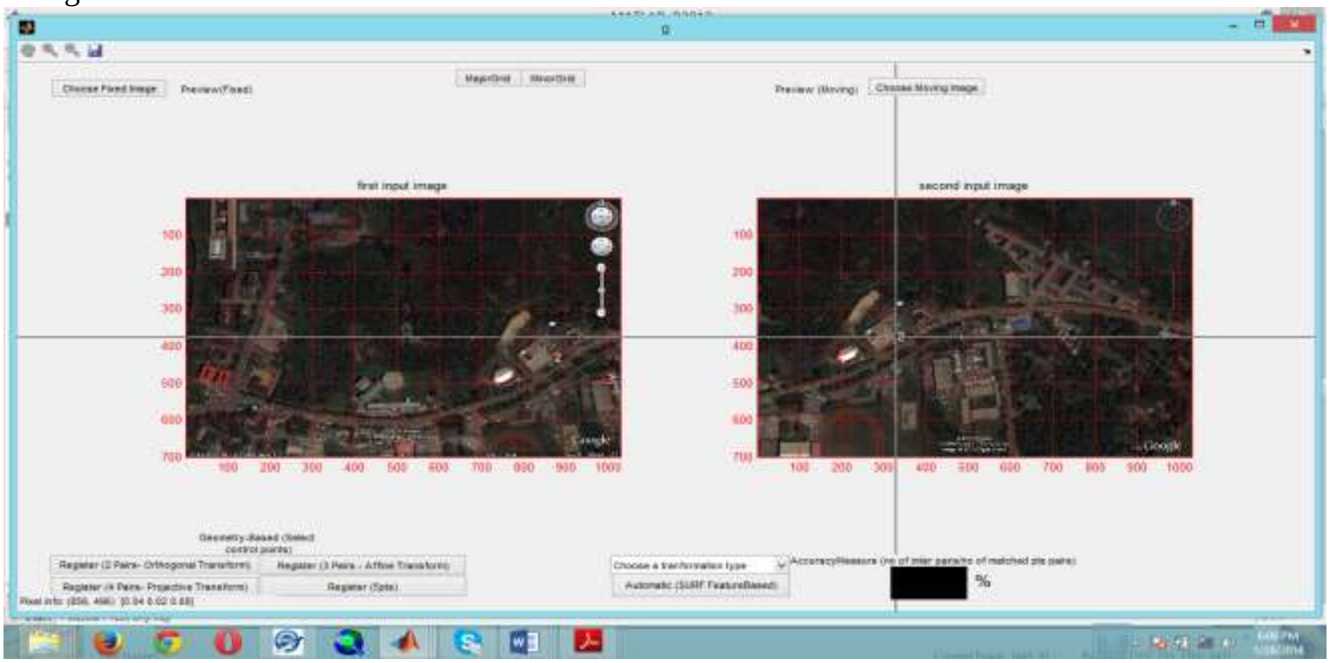

Figure 6.0a: Showing the Process of Selecting Conjugate Points on both the Base (left) Moving and Moving Image

The Coordinates of the three conjugate points selected for Affine transformation function based registration and the Computed Transformation Matrix with the root mean sqaure error are are shown in Table 2.0

Table 2.0: Table showing the Coordinates of the Conjugate Points selected (3 pairs)

	BASE IMAGE		MOVING IMAGE	
Conjugate Points Selected	Eastings Coordinates	Northings Coordinates	Eastings Coordinates	Northings Coordinates
1	851.4308	477.4727	311.7778	420.4727
2	868.3582	447.363	330.5502	390.4074
3	891.5771	456.351	352.5493	399.3536

The Computed Transformation Matrix and RMSE for Affine Transformation based Registration are:

ISSN 2053-5783(Print), ISSN 2053-5791(online)

$$Z=\begin{bmatrix}311.7778 & 420.4727 & 1.0000 & 0.0000\\ 330.5502 & 390.4047 & 1.0000 & 0.0000\\ 352.5493 & 399.3536 & 1.0000 & 0.0000\\ 420.4727 & -311.7778 & 0.0000 & 1.0000\\ 390.4047 & -330.5502 & 0.0000 & 1.0000\\ 399.3536 & -352.5493 & 0.0000 & 1.0000\end{bmatrix},\ xp=\begin{bmatrix}851.4308\\ 868.3582\\ 891.5771\\ 477.4727\\ 447.3630\\ 456.3510\end{bmatrix},T=\begin{bmatrix}0.9920 & 0.0203 & 533.3151\\ -0.0203 & 0.9920 & 66.9421\\ 0.0000 & 0.0000 & 1.0000\end{bmatrix}$$

Parameter Vector (t): a=0.9920, b=0.0203, Tx = 533.3151, Ty=66.9421, RMSE = 12.5584mm
The final result of the Affine Transformation function based registration process is herein shown in Figure 6.0b.

Using Projective Transformation

Finally, the Projective Transformation which requires the selection of four conjugate points was used and the results obtained are as shown in the figures below. Figure 7.0a presents the process of conjugate point selection, Figure 7.0b shows the Final result obtained (The registered image) while Table 3.0 shows the coordinate of the four selected conjugate point (on the base and moving image respectively).

Figure 6.0b: Showing the Result obtained (registered image) using Affine transformation.

ISSN 2053-5783(Print), ISSN 2053-5791(online)

International Journal of Engineering and Advanced Technology Studies

Vol.2,No.4,pp.1-15, December 2014

Published by European Centre for Research Training and Development UK (www.eajournals.org)

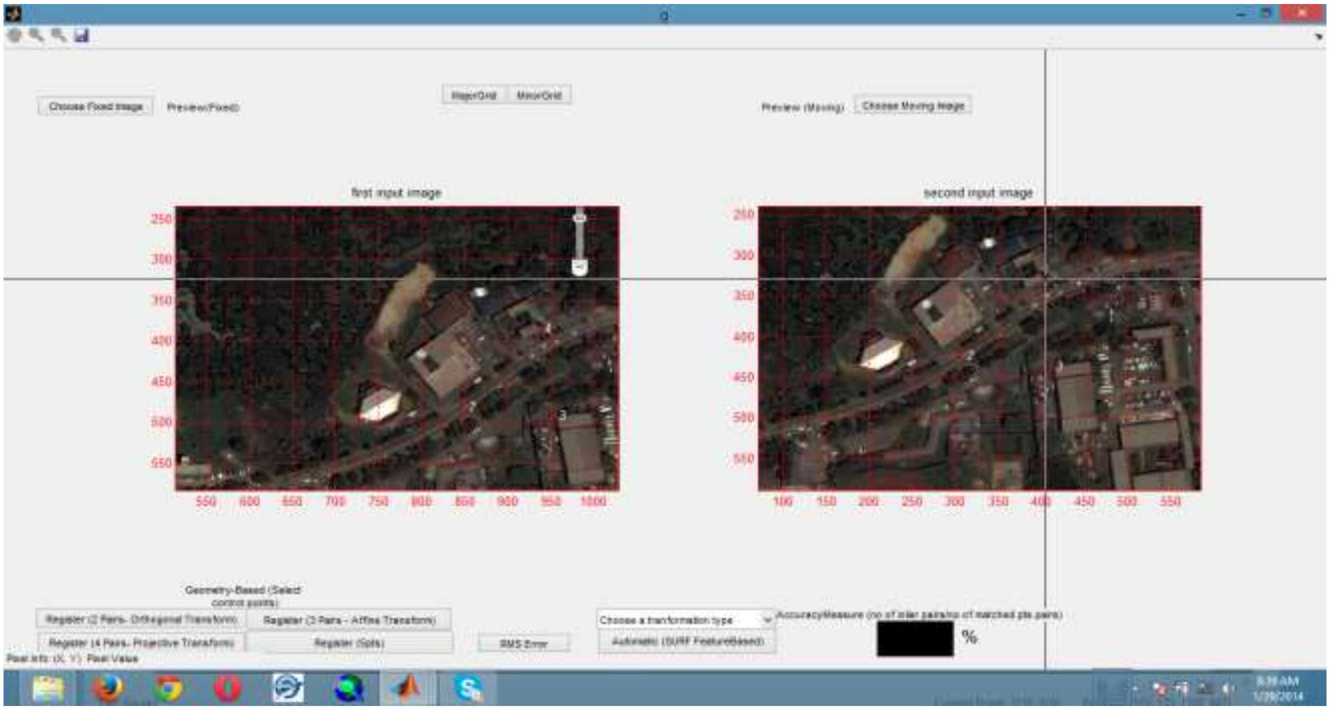

Figure 7.0a: Showing the Process of Selecting Conjugate Points on both the Base (left) Moving and Moving Image (Projective Transformation)

The Coordinates of the points conjugate points used for the registration, the Computed Prameter vector, Transformation Matrix and RMSE are shown in Table 3.0 below:

Table 3.0: Table showing the Coordinates of the selected four conjugate points.

	BASE IMAGE		MOVING IMAGE	
Conjugate Points Selected	Eastings Coordinates	Northings Coordinates	Eastings Coordinates	Northings Coordinates
1	865.5692	504.2917	323.4563	446.1206
2	851.6132	477.9303	312.809	419.5024
3	861.1756	451.0519	323.4563	394.2152
4	893.7398	454.4117	354.7326	396.877

Below are the Computed Transformation Matrix and RMSE for Projective Transformation based Registration.

ISSN 2053-5783(Print), ISSN 2053-5791(online)

$$Z = \begin{bmatrix} 323.4563 & 446.1206 & 1.0000 & 0.0000 \\ 312.8090 & 419.5024 & 1.0000 & 0.0000 \\ 323.4563 & 394.2152 & 1.0000 & 0.0000 \\ 354.7326 & 396.8770 & 1.0000 & 0.0000 \\ 446.1206 & -323.4563 & 0.0000 & 1.0000 \\ 419.5024 & -312.8090 & 0.0000 & 1.0000 \\ 394.2152 & -323.4563 & 0.0000 & 1.0000 \\ 396.8770 & -354.7326 & 0.0000 & 1.0000 \end{bmatrix}, \ xp = \begin{bmatrix} 865.5692 \\ 851.6132 \\ 861.1756 \\ 893.7398 \\ 504.2917 \\ 477.9303 \\ 451.0519 \\ 454.4117 \end{bmatrix} \quad T = \begin{bmatrix} 1.0120 & 0.0504 & 514.5919 \\ -0.0504 & 1.0120 & 69.3184 \\ 0.0000 & 0.0000 & 1.0000 \\ 0.0000 & 0.0000 & 1.0000 \end{bmatrix}$$

Parameter Vector: a=1.0120, b=0.0504, Tx =514.5919, Ty=69.3184, RMSE = 10.8980mm
The final result of the Projective Transformation function based registration process is herein shown in Figure 7.0b

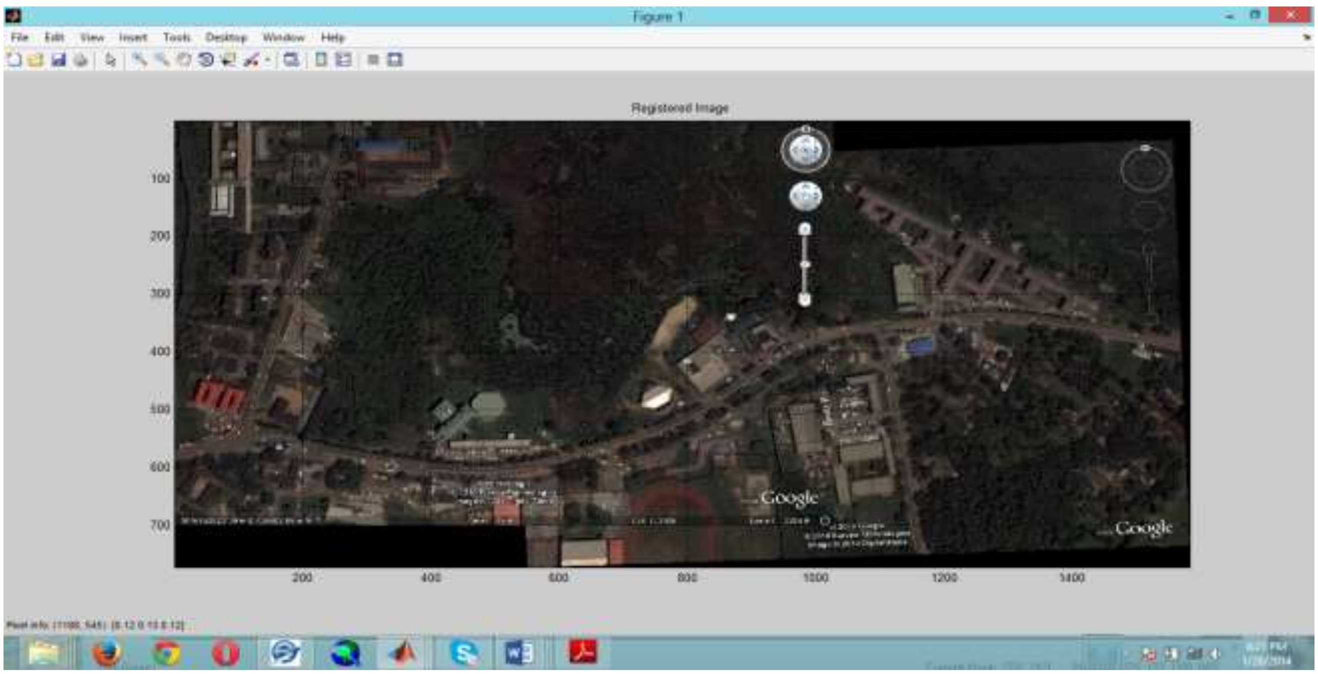

Figure 7.0b Showing the Result obtained (registered image) using projective transformation

DISCUSSION OF RESULTS

From the results obtained from the Orthogonal, Affine and Projective transformation Based semi-automatic registration with approximate Root Mean Square errors of 15.3389mm, 12.558mm and 10.898mm respectively, It can be affirmed that the transformation model that gave the most refined result is the Projective transformation, followed by Affine and then projective. This is expected because the more the degrees of freedom of a transformation mode, the better the expected result should be. Since Projective has Eight (8) degrees of freedom (4

ISSN 2053-5783(Print), ISSN 2053-5791(online)

Independent Control Points), Affine has Six (6) degrees of freedom (3 Independent Control Points) and Orthogonal transformation Four (4) degrees of freedom (2 Independent Control points), it is expected that Using Projective transformation should produce a better result than both Affine and Orthogonal Transformation based registration. It is also expected that the output of the registration process using affine transformation should be of better accuracy compared with the output of the registration process in which Orthogonal Transformation model was applied. The result obtained from the registration process using these three transformation models buttressed the above assertion. Also, it could be deduced from the result obtained that geometric or control point based registration could be highly prone to geometric distortions. Generally, the accuracy of this technique is quite poor going by the Root Mean Square deviations obtained. This is as a result of the user's inconsistency in selecting the conjugate points used for the computation of the transformation matrix (T). The more consistent and precise the selection of the conjugate points on both the base and the Moving Image is, the lesser the Root Mean Square Error, and consequently the better the accuracy of the registered image. It is instructive to note that the closer the Root Mean Square Error is to zero, the more refined and accurate the registration is. It is also important that the user be familiar about with the features of the area whose image is to be registered.

CONTRIBUTION TO KNOWLEDGE

\
The task of Image registration or mosaic generation from overlapping images is not just a function of the fusion of these images. It seeks to ensure that beyond the image fusion, the geometric integrity of the image features remains intact as it was on the individual image patches before registration. i.e; it seeks to minimize mis-match as much as scientifically possible. Image registration is not only laborious but computationally intensive due to the numerate mathematical models involved. Thus making the manual approach to image registration prone to human error (which increases mis-match) and time consuming. This research has attempted to automate the entire process of Image registration or Mosaic generation by providing a simple, user-friendly and user-assisted image registration algorithm to the research community.

CONCLUSIONS

\

- Control based method was adopted and Point was used as the primitive. Orthogonal Transformation, Affine Transformation and Projective Transformation were used for the registration which requires two Control pairs or Conjugate Points, Three Control pairs and four Control pairs respectively. Root Mean Square Error (RMSE) was adopted for the estimation of the degree of error or mismatch.
- Efficiency and Accuracy is a function of the degrees of freedom (d.o.f) of the transformation matrix. The more numbers of degree of freedom as presented by the transformation technique, the more flexible registration becomes and consequently, the better the registration efficiency and the resultant accuracy. That is, the result obtained from the registration process in which Projective Transformation was used (with 8 degrees of Freedom) produced an accuracy that is

ISSN 2053-5783(Print), ISSN 2053-5791(online)

better than the accuracy obtained from Affine Based Transformation Model. And also the result obtained from the Affine Based registration algorithm proved to be more accurate that the result obtained from the registration process which used Non-Reflective Similarity Transformation Model.

REFERENCES

1. Barbara Zitova and Jan Flusser (2003), Image registration methods: a survey, Image and Vision Computing 21, pp 977-1000, 2003.
2. C. Stamatopoulos and C. S. Fraser (2011)., An orthogonal projection model for photogrammetric orientation of long focal length imagery.
3. J. B. Campbell, *Introduction to Remote Sensing*, The Guilford Press, 1987.
4. J. R. Jensen, *Introductory Digital Image Processing: A Remote Sensing Perspective*, 2ed, Prentice Hall, 1996.
5. L. G. Brown (1992), “A survey of image registration techniques,” *Comput. Surv.*, vol. 24, no. 4, pp. 325–376.
6. L. M. G. Fonseca and B. S. Manjunath (1996), “Registration techniques for multi sensor remotely sensed imagery,” *Photogramm. Eng. Remote Sensing*, vol. 562, pp. 1049–1056, Sept. 1996.
7. Rami Al-Ruzouq. (2004), “*Semi-Automatic Registration of Multi-Source Satellite Imagery with Varying Geometric Resolutions*” Ph.D Thesis, Department of Geomatics Engineering, University of Calgary, Calgary, Alberta.

ISSN 2053-5783(Print), ISSN 2053-5791(online)