

# UPDATION AND POSITIONAL ACCURACY IMPROVEMENT OF GEO SPATIAL DATA-INNOVATIONS AT KAMPSAX INDIA PRIVATE LIMITED

S N Mahapatra<sup>a \*</sup>, V K Mahindru<sup>b \*</sup>, A K Swain<sup>a \*</sup>, Alok Upadhyaya<sup>b \*</sup>

<sup>a</sup> KIL, R&D Division, 813, Phase-V, Udyog Vihar, Gurgaon, Haryana, India - (SNM, AKS)@kampsax.co.in

<sup>b</sup> KIL, Mapping Division, 809, Phase-V, Udyog Vihar, Gurgaon, Haryana, India-(VKM,AKU)@kampsax.co.in

## PS ICWG II/IV: Automated Geo-Spatial Data Production and Updating

**KEY WORDS:** PAI, New mapping, Updation, Transformations, Geometric fidelity

### ABSTRACT:

Kampsax India Private Limited (KIL) is engaged in the production of very large mapping projects from all over the world though mainly from Europe and Latin America with over 35 digital Photogrammetric instruments working round the clock. There is always endeavour for finding new technical solutions for large volume production with high quality. KIL mainly undertakes photogrammetric projects involving Aerial Triangulation (AT), Digital Terrain Model (DTM), Orthophoto Production, 3D Vector Mapping (New Mapping/updation) and 2D Mapping (based on Orthophoto for updation and positional accuracy improvement). Two of the projects involved the use of old data sets for new mapping/updation and positional accuracy improvement (PAI), where the old vector data required to be updated and positional accuracy improved using latest Orthophoto. Another project required 3 dimensional new vector mapping with tiff raster files of old maps only as a guide. The accuracy requirement for these projects is of the order of about 1.25mt in planimetry and height. The projects required establishment of new database while maintaining absolute accuracy, relative accuracy and geometric fidelity. This paper demonstrates the development of semi-automatic method to improve the positional accuracy of old vector data maintaining the absolute and relative accuracy as well as geometric fidelity. The PAI (Positional Accuracy Improvement) apply special transformation to match with the raster image. PAI makes use of special transformation on old data with a constrained situation in order to achieve perfect matching of vector data with raster image. Geometric contraction, expansion, dilation, similarity transformations, spiral similarities, rotation and translation all affine transformations or their combinations are included in this process. The production workflow involves the tiff files of old maps digitized in 2D, locally transformed and merged with TIN data of automatically generated DTM (Digital Terrain Model) to create 3D vector data. The 3D vector data thus generated is made use for preparing updated new map database. The concept of positional accuracy improvement is further developed for use in 3 dimensions. These methods have changed the notion that old vector data cannot be used for new mapping/updation. This potential application makes use of any existing maps digital/paper for subsequent new mapping and updation.

## 1. INTRODUCTION

### 1.1 General Introduction

Decision-making demands timely up-to-date information. All over the world the maintenance of Geo-spatial data infrastructure is gaining attention and significant proportion of annual running costs of the organizations responsible is used for maintaining such data. Whatever the methodology to be adopted for maintenance for such data, it is always desirable to make use of the existing data sets. The available data sets may be in the form of existing digital vector database or the paper maps.

Kampsax India Private Ltd is actively engaged in the production and maintenance of such geo-spatial databases for different organizations world over. With 35 Digital Photogrammetric Workstations in production round the clock, it is one of the largest photogrammetric production organization offering large volume production with high quality for Aerial Triangulation, Digital Terrain Modelling, Digital and Analytical Vector Mapping, Orthophoto production using Analogue/Digital Aerial Images, Satellite Images and Laser Scanned data.

### 1.2 Detail Introduction

The paper deals with generation of updated and more accurate digital vector database starting from the existing data source. The updation of database can be considered for generation of 2/3 Dimensional vector data. In case of 2D vector data the updation and positional accuracy improvement may be carried out using latest orthophoto while for creation of updated 3D vector data latest stereo aerial photographs are used.

In one of the project handled at Kampsax India (P) Limited, the existing vector data required positional accuracy improvement and updation. The fresh aerial photographs are obtained. The required ground control for carrying out Aerial Triangulation (AT) is provided as field input. The digital terrain models are produced for obtaining orthophotos. The orthophotos thus produced is used as reference for positional accuracy improvement and updation.

---

\* The authors are presently working with Kampsax India Private Limited, Gurgaon, Haryana, India and are engaged in Photogrammetric Mapping of International Projects at one of the biggest Photogrammetric Production Centre of India. Use appropriate person in cases with more than one author.

In the other project the digital vector data was not available. The existing maps are scanned and 2D Vectorization of the features carried out for subsequent use in the positional accuracy and updation process.

## 2. POSITIONAL ACCURACY IMPROVEMENT (PAI) & TRANSFORMATION REQUIREMENT

### 2.1 PAI

This process assumes existing data is relatively correct and Geometric/Absolute accuracy is within specified tolerance limits. In this process, attempt is made to improve the accuracy of existing data. The user must specify the amount of displacement required at several well distributed points throughout the map using the available information from ground survey or latest orthophoto or stereo model.

Positional Accuracy Improvement (PAI) requires a special kind of transformation to the vector data to improve the overall accuracy with minimal change to the following accuracies. The allowable limit varies depending upon the scales of data sets, but the basic principles remains the same.

*Relative accuracy:* It is a measure of how close is the distance of a line measured on map agrees with the corresponding distance measured on ground.

*Absolute accuracy:* It is a measure of how close is the co-ordinate of a point on map agrees with the corresponding co-ordinate of the point measured on ground.

*Geometric fidelity:* It is a measure of how closely the feature on the map matches the real-world shape and alignment

### 2.2 POSSIBLE SOLUTION FOR PAI

In order to maintain the relative, absolute and geometric accuracy within required tolerance limits while carrying out transformation, is rather complicated. Solution can be achieved in 2 steps

1. Identifying required displacement
2. Applying special transformation for PAI

Again it may not be possible to notice the amount of shift required at all the places through out the map, especially where accuracy matters the most. The amount of shift has to be identified on raster Orthophoto, where it can be identified.

The solution for special transformation for PAI can be divided into two parts.

1. Defining the smallest area, which will act as transformation unit.
2. Defining transformation formulae, which ensure smooth transition across such unit areas.

#### 2.2.1 Defining unit area for transformation.

One kind of transformation can't ensure that the displacement at all points is same as desired. Traditional affine transformation can ensure this in side a triangle and projective transformation can ensure the same inside a quadrangle. Expansion, geometric contraction and dilation of the affine transformation do work in a particular direction but the requirement of the project is quite complicated. For example expansion is an affine transformation, in which the scale is increased and it is opposite of the geometric contraction. This is not the single requirement because apart from scaling it has to take care of rotation and translation. Since controlling the amount of displacement across the edges of the triangle is more complicated, it was decided to

divide the whole area into small triangles based on Delauney triangulation, which will lead to a better control of smooth transition across the edges.

#### 2.2.2 Defining Type of transformation.

Many of the traditional approaches used for PAI are based on one of the following possible methods.

1. Inverse distance function
2. Inverse square of distance, (acts like potential field).
3. Affine transformation.

Type 1 & 2 transformation approach will simply not work for such transformation in side a triangle as there is a need to guarantee the smooth transition across edges. Type 3 uses differential scaling in different directions, making it difficult to control scaling factor throughout the map.

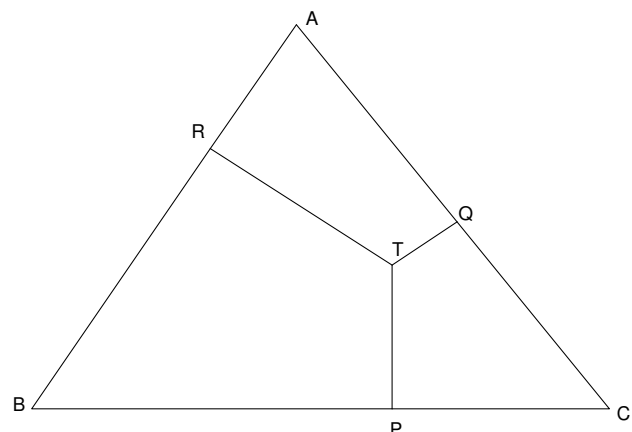
So the need is to opt for a simple weight based transformation solution, which will localise the transformation in the triangle (the effect of displacement should not be distributed over the complete map). The requirements are as follows

1. At corners resultant displacement should be same as specified displacement
2. Smooth and gradual change across such unit areas
3. Transformation should be smooth inside the triangle
4. Retain existing relative, absolute & geometric accuracy

Out of few possible solution for defining distribution of Weights inside a triangle following methods were tried

1. Weight proportional to distance from opposite sides
2. Weight proportional to the area of triangle formed with other 2 vertices

### 3.1 TRANSFORMATION USING WEIGHT PROPORTIONAL TO DISTANCE FROM OPPOSITE SIDES



(Figure -1 Weight proportional to distance from opposite sides)

The Weight of displacement vector at point T are calculated as follows

$$\begin{aligned} WtA &= TP / (TP+TQ+TR) \\ WtB &= TQ / (TP+TQ+TR) \\ WtC &= TR / (TP+TQ+TR) \end{aligned} \quad (1)$$

Where  
 ABC = Three corner points of the triangle  
 T = Any point inside the triangle  
 Wt= Weight-age of the point as per the displacement vector

This method satisfies criteria 1 & 2. This method produced good results except near some edges of the triangle. It was found that the weight distribution of displacement vectors is not uniform on both sides of those edges where triangles are not uniformly shaped.

Hence there was a need to devise a transformation, which would ensure smooth distribution of weight on both sides of the edges. Transformation using weight proportional to the area of triangle formed with two other vertices satisfies the same.

### 2.3 Transformation using weight proportional to the area of triangle formed with two other vertices

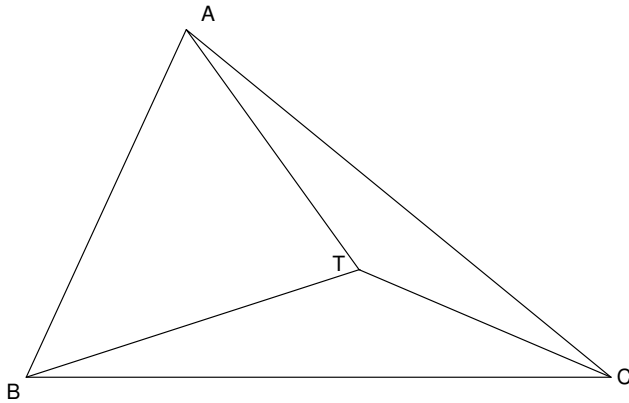


Figure 2. Weight proportional to the area of triangle formed with two other vertices

The weight of displacement vectors are calculated as follows

$$\begin{aligned} WtA &= \text{Area of TBC} / \text{Area of ABC} \\ WtB &= \text{Area of TCA} / \text{Area of ABC} \\ WtC &= \text{Area of TAB} / \text{Area of ABC} \end{aligned} \quad (2)$$

Where  
 ABC = Three corner point of the triangle  
 T = Any point inside the triangle  
 Wt= Weight-age of the point as per the displacement vector

This method acts like a transformation based on inverse distance method (controlled by displacement vectors at both ends) at the edges of triangle. Thus it satisfies the criteria 3 in addition to 1 & 2. This method produce good results throughout the map except some angular changes especially where vertices are too close to each other.

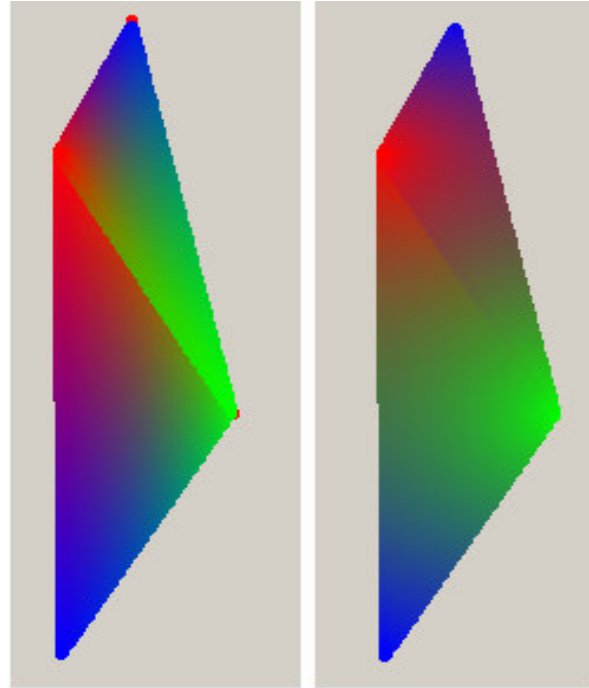


Fig. 3. Weight distribution based on distance to opposite sides on left. Weight distribution based on area of triangle on right.

#### 2.3.1 Final PAI Transformation Equations:

Equation 2 was used for controlling transformation inside the triangles, which were formed based on Delauney Triangulation. The resultant displacement at each point is calculated using weight factors as below.

$$\begin{aligned} \text{Displacement at point T} &= \\ &WtA * [\text{Displacement Vector at A}] \\ &+ WtB * [\text{Displacement Vector at B}] \\ &+ WtC * [\text{Displacement Vector at C}] \end{aligned} \quad (3)$$

Where  
 WtA, WtB, WtC = the weight factor of the displacement vectors at A, B, C respectively.

As the total area is divided into triangles and this transformation applied inside each triangle ensures that displacement at corners is same as required, in order that absolute accuracy inside each triangle is achieved. Better geometry of triangle formed based on Delauney Triangulation ensures relative accuracy. It is important to identify displacement in such positions which will form better geometry for Delauney Triangulation.

Thus it ensures that at the edges of triangle only two displacement vectors (specified at both ends) control the displacement, which in turn ensures smooth displacement across edges of the triangle. This method also ensures smooth transition of weight factors, but still produces angle error at places where feature spans across several triangles. Hence special auto-correction logic was introduced to ensure geometric fidelity is perfectly restored for all the features.



Figure.4, The left figure shows before PAI and right after PAI operations

A set of rotation, scaling & translation factors were calculated based on least square method technique, which will transform original feature to the transformed feature. These parameters may be modified to take higher order transformation. But using higher order will allow bending of objects (which spans across several triangles), thus improving relative accuracy but geometric errors gets introduced. The original object is transformed with these rotation, scaling and translation parameters, to re-establish original geometry.

## 2.4 Updation

The updation of geo-data requires the detection of changes between up-to-date geo information and the existing data set. In case of manual updation of the data, the operator decides if the stored object has changed. The automatic updation process requires a similar decision, which means that the extracted object have to be compared with the stored object. As the PAI considers the latest orthophoto or stereo model is concerned, manual changes are required to be captured for new objects. The updation is carried out using unit area over which PAI operation is carried out as tile. For obtaining absolute accuracy for the changes on the ground the following checks are required.

1. Nodes are not breaking in the tile edge.
2. There should not be any duplicate tile edge beneath the original tile.

## 3. UPDATION AND POSITIONAL ACCURACY IMPROVEMENT FOR 3 DIMENSION

### 3.1 Preparation

Another innovation developed at KIL made use of existing scanned paper maps for production of updated new maps in 3 Dimensions using stereo images.

The existing stereo aerial images are used for obtaining digital terrain information by automatic terrain extraction. An in-house program was developed to obtain the height information (from digital terrain model) of corresponding plan metric points in the vectorized maps. The height information is obtained from automatically generated digital terrain model as TIN data of the corresponding stereo images. Thus the Automatic program

merges Z value from DTM data with X, Y values from 2D digitised file. 3D vector data so obtained is now ready for Positional Accuracy Improvement and updation.

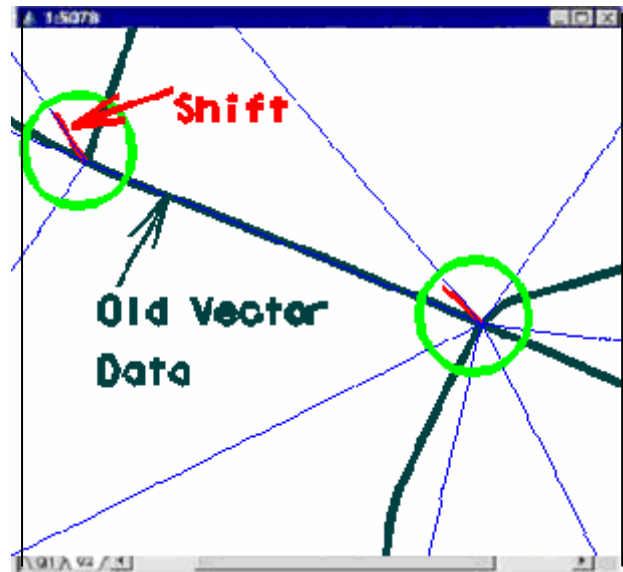


Figure.5, Links are provided for shifting the vector, black features are old vector data and green circles show the shift required for Positional Accuracy Improvement

### 3.2 Applying PAI

After the links are placed and triangles are generated the PAI tool does the Positional Accuracy Improvement over 3-dimension. The red marks show the displacement required with respect to old vector data.

A typical out put of the Positional accuracy improvement of vector data is shown below.

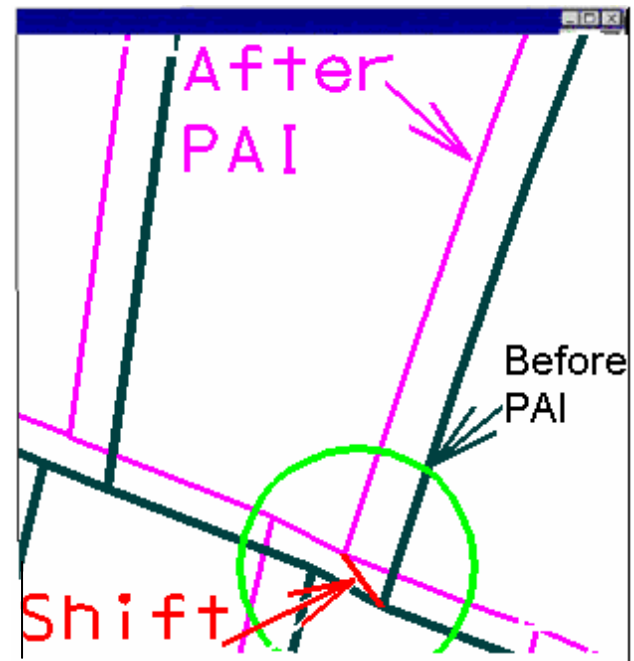


Figure.6, Transformation before (features in black) and after PAI (features in magenta), desired shift or links (in red)

New production method has increased the efficiency of the production process and made it easier for the plotting operators with most of the work done automatically maintaining required specification for the project. The process also helped in retaining the shapes of the cadastral boundaries as given in the old maps/scanned images.

## 5 CONCLUSION

The past notion that old vector data cannot be reused for production of new and more accurate maps/digital database has changed. Not only the old vector data can be made use of for positional accuracy improvement but also the paper maps have been successfully made use by simple digitisation for subsequent positional accuracy improvement and updation. The new methods have been developed and implemented at Kampsax India Private Limited for 2 Dimensional and 3 Dimensional databases for Updation of Geo Spatial Data Bases using Orthophoto and stereo images as reference.

## 6 REFERENCE

### References from Journals:

### References from Books:

Wise Stephen.2002 *GIS Basic*, New York: Canada: Algorithms for Surface, PP 163

Ball, W. W. R. and Coxeter, H. S. M. 1987,*Mathematical Recreations and Essays, 13th ed.* New York: Dover,.

Coxeter, H. S. M. and Greitzer, S. L. , 1967"Dilation." §4.7 in *Geometry Revisited*. Washington, DC: Math. Assoc. Amer., pp. 94-95.

Hilbert, D. and Cohn-Vossen, 1999 *S. Geometry and the Imagination*. New York: Chelsea, p. 13.

Stott, A. B. 1910. "Geometrical Deduction of Semiregular from Regular Polytopes and Space Fillings." *Verhandelingen der Koninklijke Akad. Wetenschappen Amsterdam* **11**, 3-24,

### References from Other Literature:

Smith, J., 1987b. Economic printing of colour orthophotos. Report KRL-01234, Kennedy Research Laboratories, Arlington, VA, USA.