Planimetric Quality Assurance of the LANDMAP mosaic: methods and results

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Abstract

The LANDMAP project has produced orthoimages which have been geocoded with a DEM derived from Interferometric SAR. When the project is finished a mosaic of the whole of the UK will be available. In addition the DEM will be used to create orthoimage mosaics from SPOT and Landsat images. These data sets will all be validated to assess their planimetric quality. Because of the large amounts of data involved and the problems in identifying ground control points, automatic methods are desirable. This paper discusses the reference data available and methods used for the validation. At the time of writing only preliminary results are available.

1. Introduction

The validation of Digital Elevation Models (DEMs) at any scale is of great importance if the data is to be used with confidence by itself or for the production of orthoimages. To carry out this task efficiently, accurate reference data is required and some automation is desirable to ensure that checks can be carried out on significant areas of the data set and that this can be done accurately. The manual selection of check points is both time consuming and prone to error.

The LANDMAP project has generated a DEM of the whole of the United Kingdom and Ireland from ERS Tandem data. The DEM is being used to geocode the SAR data and to create a mosaic of the whole area. This paper is concerned with the validation of the mosaic using a number of sets of reference data.

The LANDMAP products should be able to be well validated because good reference data is available, or can be acquired conveniently without expensive field campaigns. The principle methods available are the use of existing cartographic datasets and the use of GPS data captured specifically for the purpose of control and validation of the data. The initial validation is being done on geocoded SAR data by registering the image data to existing reference data. The SPOT and Landsat data will be validated also by reference to the SAR data. Hence image to map registration and image to image registration is necessary.

This paper starts by discussing the reference data available, the methods used and the results. There is then some discussion on improving these methods by the introduction of automatic processes.

2. Data

A number of data sets are available and are listed and described in table 1. In selecting the most suitable reference data and method of validation a number of key factors must be considered:

- the data set is very large and includes different types of terrain and different land cover;
- validation of a significant sample of the dataset can only be done if automatic tools are available;
- different users expect different accuracy.

Accordingly a tiered approach was adopted in which visual assessment was done on the whole area but quantitative assessment based on selected check points was done with limited number of points.

Dataset	Characteristics	Comments
OSCAR®	Vector data set of UK roads based on 1:50 000 digitised maps.	Useful when overlain on SAR data as full pattern can be seen. Co-ordinates of points can be extracted.
Bartholomew's	Map coverage of UK derived from 1:250 000 maps.	All features available but scale too small, and too much generalisation to be useful for validation.
PROMAP®	Ordnance Survey large scale vector data which can generate co-ordinates of selected points with an accuracy of between 1m and 3m depending on area.	Accurate point data but output can only be manual. No definitive specification of accuracy for each point.
Kinematic GPS traverses (Cross et al., 2000)	Traverses along roads with accuracy of about 2.5m in X, Y, and Z with 20 spacing.	Accurate data which follows roads and also gives elevation

Table 1. Characteristics of the data sets available.

3. Methods available

A number of traditional and new methods of validation are available, these are described and their suitability for LANDMAP discussed in this section.

3.1 Check points

This is the traditional way of checking map data. A number of well distributed points are chosen over the area. These should be of higher accuracy than the data. Stuttard et al (1998) suggest a factor of 1:2 as being a suitable ratio of the accuracy between control points or check points and expected accuracy of the product.

Check point co-ordinates can be derived from existing maps, but great care must be taken in using this method as error will accrue from distortion of the map, generalisation at scales smaller that 1:10 000 and measurement. PROMAP® is a useful tool for selecting co-ordinates because it allows the co-ordinates to be derived directly from the digital data base. No numerical output is possible using PROMAP® and the co-ordinates would have to be entered into any analysis tool used. Stuttard et al (1998) have reported on the analysis of ERS-1 and SPOT data in this way. Co-ordinates of road intersections can also be derived from OSCAR®, using a package such as ARC/Info.

The error associated with checkpoints (which can be termed a discrepancy to distinguish it from a residual derived from a check point) can be measured at any time on the geometrically corrected image. A residual or discrepancy is defined as:

$$v_x = x_r - x_i \quad \text{and} \quad v_y = y_r - y_i \qquad (1)$$

where x_i, y_i are the source co-ordinates, and x_r, y_r are either the re transformed co-ordinates (for residuals) or the check point co-ordinates (for discrepancies). The vector error is given by:

$$v_{xy} = \sqrt{v_x^2 + v_y^2} \qquad (2)$$

The total rms errors in x and y are given by:

$$rmse_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_r - x_i)^2} \qquad rmse_y = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_r - y_i)^2} \qquad (3)$$

Hence, the total rmse is given by:

$$rmse_{xy} = \sqrt{rmse_x^2 + rmse_y^2} \qquad (4)$$

Whilst this method gives an excellent assessment of the accuracy of the product, the task of selecting sufficient point points with an ideal distribution is very time consuming. With SAR data this problem is exacerbated because of the nature of the image. Linear features in SAR do not show as continuous heavy lines and when viewed with the pixels visible it is often impossible to determine the centre of a road intersection. Figure 1. illustrates this problem.

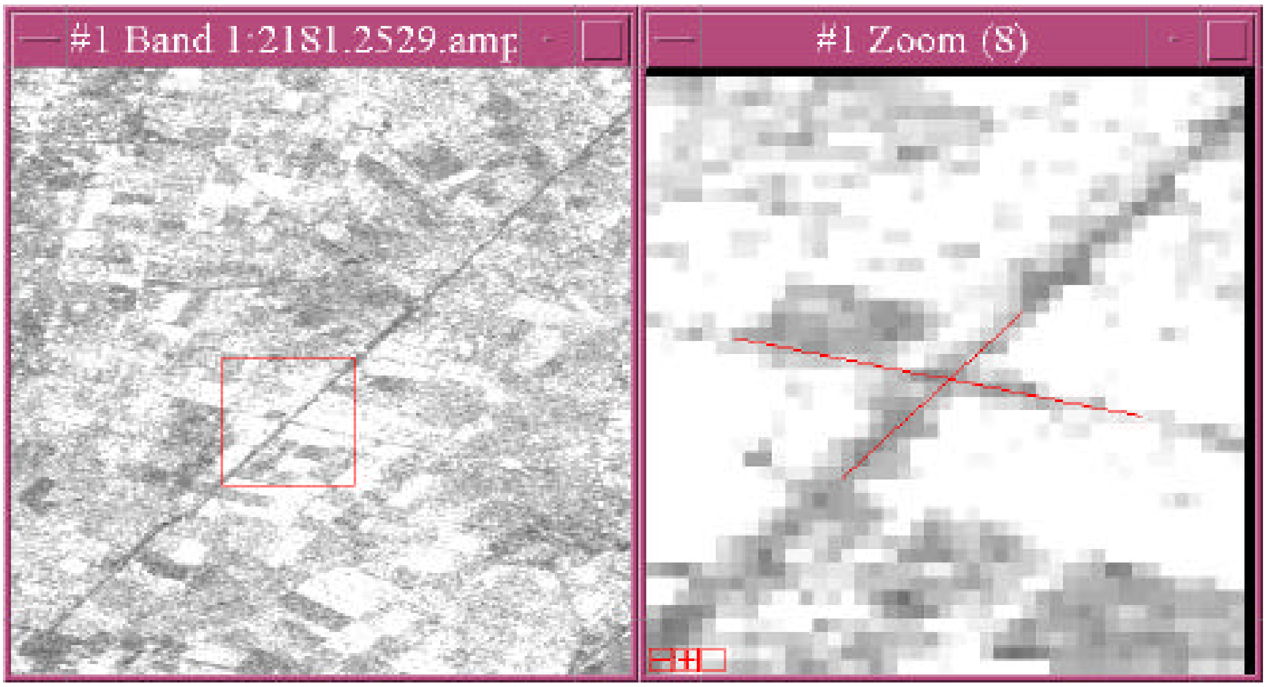

Figure 1. A road intersection shown at small scale with a road intersection clearly visible, and zoomed with the pixels visible. The cross has been overlain to indicate the probable position of the intersection.

There are several methods of overcoming this problem which are discussed below.

3.2 Visual validation

A way of overcoming the time required to validate using check points and to compare the position of linear features is to overlay the image data with features such as roads, railways, water or land cover such as woodland. This allows a direct comparison to be made between lines, rather than points. Using a data set such as OSCAR®, it also gives a rapid validation of the whole area covered by the OSCAR® data. The same could be done with the GPS traverses and with data sets such as the Bartholomew's data, but the latter is not accurate enough in this case. Overlaying the Bartholomew's data does however aid the identification of features and allows the removal of ambiguity between roads and railways for example.

The disadvantage of overlays is that it gives no quantitative analysis. The following section suggests methods of overcoming this.

3.3 Quantitative analysis of overlays

Using the overlay as a guide it should be easier to identify features such as road junctions but to assist in this a deformable cursor could be used. If the relevant section of the overlay was cut from the overlay layer and moved to the best fit position of the image, a position could be estimated quickly and points which were easiest to identify could be selected and measured. An alternative method could be to automatically match the image with a template derived from the overlay. Klang (1997, 1998) has developed a method of automatic extraction of road junctions from SPOT data and the matching of these with a window from the corresponding map.

3.4 Automatic registration

The ARCHANGEL European Commission 4th Framework project has developed a number of tools for matching images with maps. The basic techniques which are used are the extraction of line and area features from image and map and then the matching of these features. The polygon is the main feature used. These are extracted from vector data by selecting features with an appropriate attribute, for example lakes, forests or field boundaries. The polygons are extracted from the images by segmentation which is refined by applying a registrability index to eliminate polygons which are unlikely to give a match (Ruskoné and Dowman, 1997).

The basic techniques of matching polygons is adapted from Abbasi-Dezfouli and Freeman, (1994). Polygons are characterised by a number of parameters such as shape and area. Shape is defined by a bounding rectangle, parallel to defined axes, and also by the chain code method described by Abbasi-Dezfouli and Freeman. When this technique is used for validation no initial translation is needed as image and reference data are in the same co-ordinate system.

Once established the corresponding polygons must then be exactly matched in order to extract conjugate points. A method of dynamic programming developed at UCL is one method of doing this, (Newton et al, 1994). The perimeter of the feature is followed and a best fit obtained. Costs are determined by a number of measures relating the predicted edge pixel position projected into the map and the edge pixel under consideration. The difference in gradient direction between the map boundary pixel and the edge pixel under consideration are also used as costs. The method also allows the detection of changes between the two polygons which may represent true change or an error in detection, in either case such points will not be selected as conjugate. The technique makes allowance for the fact that the image may be distorted due to terrain effects or geometric effects from the camera or sensor.

This method is ideal for validating orthoimages because the image and the reference data are already registered and the use of overlays allows suitable features to be quickly selected.

3.5 Image to image registration

Once the quality of the SAR data has been established the SPOT and Landsat data can be validated by reference to this using image to image registration. Dowman and Dare (1999) have described a method of automatic registration of images of different types and of images with vector data. The basic techniques which are used are the extraction of line and area features from an image and/or a map and then the matching of these features. The polygon or patch is the main feature used as described in section 3.4. The polygons can be extracted from the images by thresholding, homogeneous patch detection or segmentation. The technique has been used to match SAR and SPOT data and results show that registration of complete satellite images can be achieved.

4. Expected Results

The planimetric accuracy of a geocoded SAR image is dependent on many factors. These include:

- The rigor of the geocoding algorithm and available control - ERS data can be transformed without control, or with only 2 GCPs but RADARSAT may need more;
- Terrain - much better results are expected in flat areas;
- DEM - obviously the better the DEM the better the geocoded image;
- The landcover - this does not effect the accuracy as much as the evaluation of the accuracy as few features can be found for checking purposes.

Treibnig and Raggam (1989) have determined the standard deviation of an ideal DEM with no measurement error for different terrain types and different grid spacing; their results are shown in table 2.

Terrain type	**Grid size**			
	10m	20m	30m	50m
Mountainous	0.64	1.16	1.65	2.57
Granite bedrock	0.33	0.52	0.68	0.97
Flat farmland	0.20	0.30	0.39	0.54

Table 2. Errors in a DEM due to variations in grid size with no measurement error.

These figures will be reflected in the accuracy of the orthoimage where the terrain has a great significance and the effect of an error in the DEM will be much greater in areas of high terrain than in flat areas.

Published results show varying accuracies. OEEPE (European Organisation for Experimental Photogrammetric Research) conducted a test of the accuracy of geocoding (Dowman, 1996), in which a number of European organisations tested geocoded ERS SAR image against a set of control points. The results are summarised in table 3.

Organisation	**Rmse (m) on check points**		
	No	E	N
DLR, Germany	9	9.2	4.8
Telespazio, Italy	30	17..9	18.5
ISTAR, France	27	11.4	8.0
ICC, Spain	23	17.4	18.9

Table 3. Accuracy of geocoding ERS-1 SAR from the OEEPE test.

Palà and Corbera (1994) from ICC produced a geocoded mosaic of Catalan, using a DEM with 15m spacing and rmse in height of 2.5m and achieved a rmse of 24.75m in x and 26.12m in y fom 24 check points.

Studdard et al (1998) reported on correction of ERS-1 data to Ordnance Survey grid co-ordinates in a flat area in Staffordshire using polynomial correction, and found rmse errors of 58m in E, 38m in N and 39m in elevation

For the LANDMAP project the pixel size in the SAR orthoimage is 1 arc second and in areas of flat to medium terrain, accuracies of less than 1 pixel would be expected. In hilly areas because of reduction of accuracy of the DEM and in the accuracy of the reference data, much higher figures are expected.

5. Results

At the time of writing the validation is in progress. The use of overlays has confirmed that these give an excellent overall impression of the quality of the data. The OSCAR® data and the GPS data fit very well to the orthoimages as shown in figure 2.

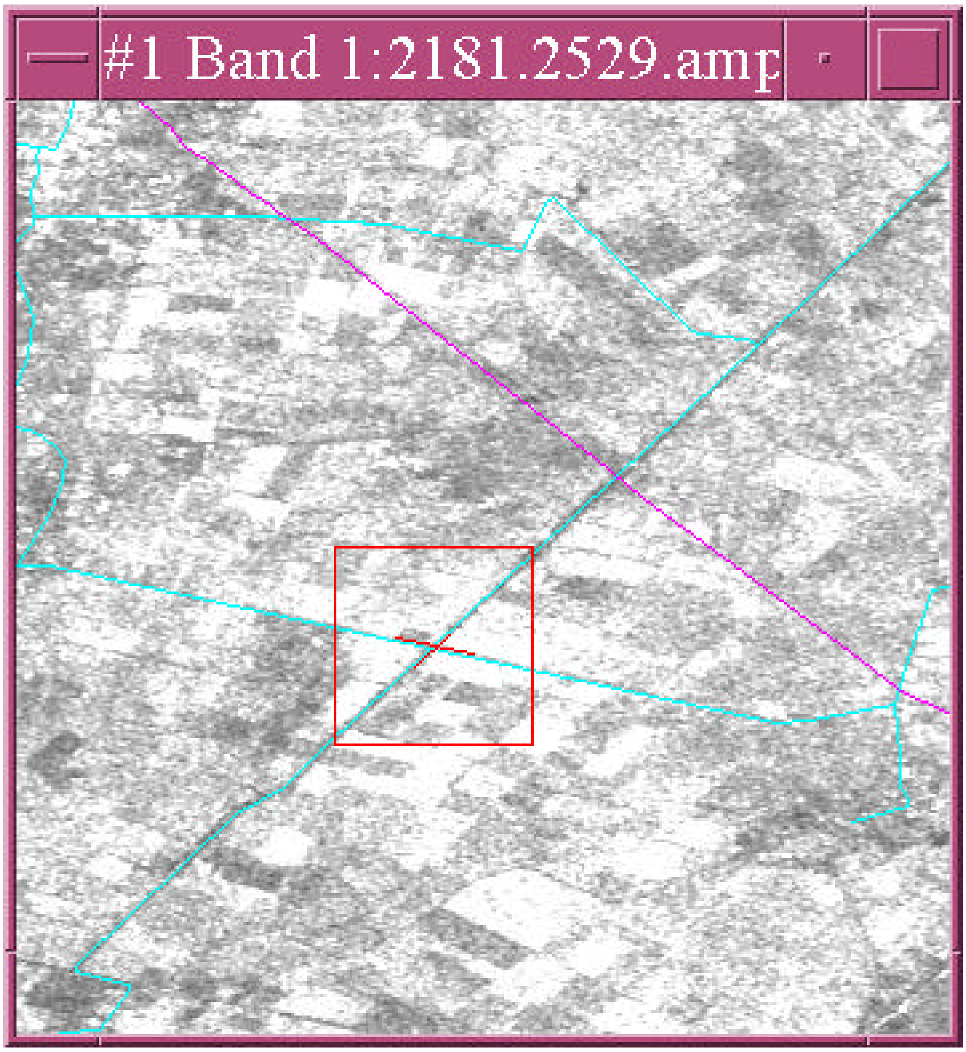

Figure 2. Part of the image of strip 2 showing the OSCAR data (blue) and the Bartholomew data (purple) overlain. The red cross within the box is a selected check point.

The GPS data is clearly better and shows dual carriageways and overpasses. The Bartholomew railway data does not fit well and clearly shows the effect of generalisation.

The strips were evaluated by selecting suitable control points and comparing the co-ordinates derived from the image and from the OSCAR® data . To date three strips have been checked. these cover the South East part of England. Figure 3 shows strip 1 which stretches from the Isle of Wight to the Humber estuary.

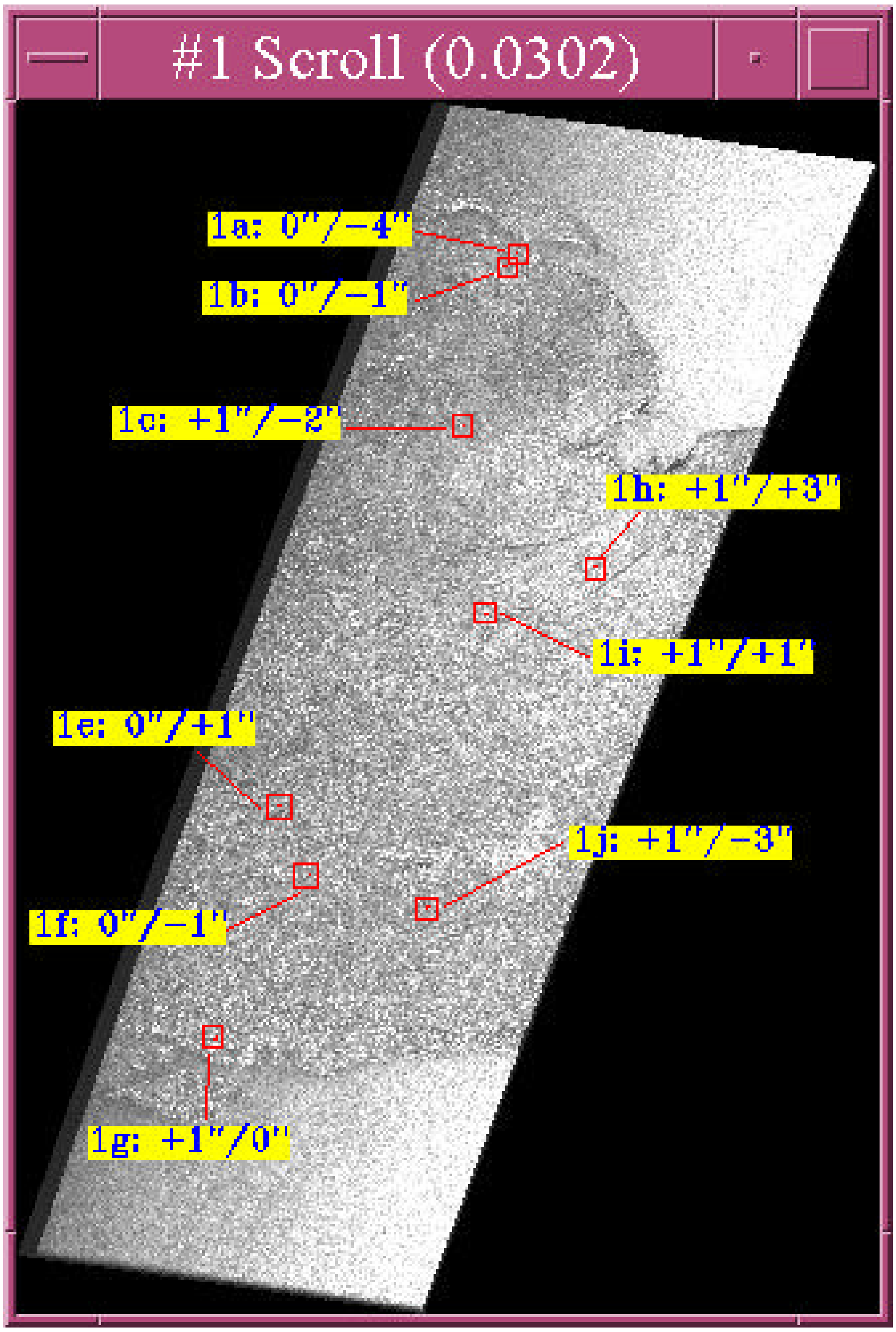

Figure 3. Points selected for validation on strip 1, together with their planimetric (x,y) deviation.

The discrepancies from all points are shown in table 4. which shows the discrepancies in latitude and longitude, pixel and Easting and Northing.

Point no	Strip	Diff lat "	Diff long "	Diff N pixel	Diff E pixel	Diff E m	Diff N m
a	1	0	-4	0	-4	0	-120
	2	0	-5	0	-5	0	-150
b	1	1	-1	1	-1	30	-30
	2	1	-2	1	-2	30	-60
c	1	1	-2	1	-2	30	-60
	2	1	-2	1	-2	30	-60
d	2	1	-1	1	-1	30	-30
e	1	0	1	0	1	0	30
	2	1	0	1	0	30	0
f	1	0	-1	0	-1	0	-30
	2	0	-1	0	-1	0	-30
g	1	1	0	1	0	30	0
	2	0	-3	0	-3	0	-90
h	1	1	3	1	3	30	90
i	1	1	1	1	1	30	30
j	1	1	-3	1	-3	30	-90
k	2	1	0	1	0	30	0
l	2	1	-1	1	-1	30	-30
m	2	0	-1	0	-1	0	-30
3a	3	2	0	2	0	60	0
3b	3	1	2	1	2	30	60
3c	3	1	-2	1	-2	30	-60
3d	3	1	3	1	3	30	90
3e	3	2	-2	2	-2	40	-40
Mean		**0.79**	**-0.88**	**0.79**	**-0.88**	**22.92**	**-25.42**
rmse		**0.59**	**1.98**	**0.59**	**1.98**	**16.28**	**59.20**

Table 4. Discrepancies on check points from 3 strips.

A number of observations can be made about the process of validation.

- It is very difficult to select point features from the SAR data with 1 arc second pixel size. Once the pixel structure becomes visible then the structure of features is lost. It took several days work to identify 8 suitable control points.

- In hilly areas, features such as roads are completely lost on the image.

- Water features show up clearly but no accurate data base of the coastline is available.

The results show that the discrepancies in the Northing direction, which is approximately along track, are within the expected accuracy discussed above, furthermore these errors are all positive which suggests a systematic shift which is not inconsistent with other work on SAR without the use of control points. The Easting, or across track discrepancies are larger and show a general trend to be negative, again indicating a systematic shift. Where points have been measured in two overlapping strips the discrepancies agree well, with the exception of point g. This suggests either a constant range error, or an error in identification which is similar in both strips. Given that the whole process has been carried out without the use of control points, the result is remarkably good.

A full quantitative analysis is being prepared and will be the subject of a future publication.

6. Conclusions

The work done so far indicates that good accuracy has been achieved in the mosaic derived from ERS SAR geocoded from the interferometric DEM and that once some problems with shifts have been resolved the road network from the OSCAR® data will register to within one or two pixels on the flat areas. This is the expected level of accuracy. Further checking with control points selected from OSCAR® data is hampered by the difficulty of selecting points from the SAR image. Further work must concentrate on the use of automatic techniques to extract points and features for registration and checking.

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