
GEOGRAPHICAL DATABASES FOR THE USE OF RADIO NETWORK PLANNING

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ABSTRACT

Radio network planning requires specific format of geographical information. This includes planning area topography and morphography. Conventional methods to produce this data can be time consuming and results are not always as accurate and up to date as hoped. New methods for fast and reliable data production have to be considered by professional data suppliers, like Geodata Oy. Production of remote sensing based geographical data for the needs of radio network planning is discussed. Use of InSAR derived DEM's and multispectral satellite image based morphographic maps were verified.

1 INTRODUCTION

At this moment mobile phone industry is one of the fastest growing industries in the world. All over the world growing number of mobile phones require more extensive coverage areas. In coverage area planning locations and number of network sites are optimized. Coverage area planning requires special format of geographical data. Topography and morphography are the most important geographical data required. Topography contains information about elevations in planning area. Different land cover types according to their wave propagation abilities define morphographic map. The other geographical data includes different types of vector data, for example road network and accurate building information. Spatial resolution of data depends on the level of planning. Small scale and medium scale (spatial resolution from 20m to 100m) data are used to cover large areas like countries or administrative districts. Large scaled (spatial resolution from 1m to 5m) data is used in smaller areas like cities. Conventionally geographical databases are produced from existing maps and vector databases or aerial photographs. Sometimes there is no guarantee of the accuracy of source material, if they are up to date or if they are available at all. Because of these, there is a need for accurate, time and expenses saving method with global coverage to produce required databases. Remote sensing based materials and methods provide an alternative way to produce or up-date required databases. (Tiihonen, 1997)

Rapid development in technology in the field of Interferometric Synthetic Aperture Radar (InSAR) offer efficient and accurate way to produce DEM's for the needs of radio network planning. It has been proven by Zebker et al. (1994) that DEM with relative errors of 5 m rms or less can be derived from InSAR ERS-1 data. ERS-1/2 Tandem Mission (1995-1996) produced extensive coverage of InSAR data with one day temporal baseline. Recent Shuttle Radar Topography Mission (SRTM) acquired InSAR data with global coverage. DEM's with a few meters vertical accuracy are generated from SRTM data.

Satellite images have been used to map land cover for a quite long time. Continuity of satellite programs like Landsat and SPOT has produced extensive data sets with spatial resolution from 20m to 30 m. More recent satellite programs like IKONOS offer large improvements to the spatial resolution of multispectral and panchromatic data. Multispectral satellite images offer possibility to produce up to date morphographic maps with varying resolutions.

In this paper production of medium scale geographical database is discussed. ERS-1/2 SAR data was used in DEM generation. Landsat Thematic Mapper (TM) image was used to produce morphographic map. IRS-1C panchromatic image was used in road network updating.

1.1 Requirements set for the geographical data

General requirements set for the geographical data are up to date source material, spatial resolution and specified data format. Source material is usually expected to be no older than five years. Vertical accuracy set for InSAR derived DEM's are presented in table 1.

| Horizontal resolution (R) in meters | Height accuracy in meters |
|-------------------------------------|---------------------------|
| 10 | $< 0.2 * R = 2$ |
| 20 | $< 0.2 * R = 4$ |
| 50 | $< 0.2 * R = 10$ |
| 100 | $< 0.2 * R = 20$ |

Table 1. Required vertical and horizontal accuracy for InSAR derived DEM.

European Telecommunications Standards Institute (ETSI) has carried out standardization of morphographic classes. This standard is presented in COST 207 report. Classes defined in this report were modified a little to produce more meaningful classes for this study. Classification accuracy was expected to be around 90 per cent. Used morphographic classes are presented in table 2.

| Morphographic class | Definition |
|---------------------|---|
| Water | Open water: sea, lakes and rivers |
| Open | Open areas: fields, open rural areas, roads |
| Rural | Areas with some trees and bushes |
| Forest | Forested areas |
| Sub-urban | 1 or 2 story buildings |
| Urban | Building height 10-25 meters |
| Industrial | Industrial areas |

Table 2. Defined morphographic classes.

Vector data included four different road classes and railroads. Only main roads and larger local roads are included in. Defined road classes are: dual lane road, federal highway, connecting road, main streets and railways.

1.2 Test area

Test area is located in southern part of Finland, north east of Helsinki. Test area includes urban centers like Järvenpää, Kerava, Hyvinkää and Mäntsälä. Size of the area is 45 km * 43 km. Test area includes multiple land use classes like boreal forest, urban areas, agricultural fields, open areas and lakes. There are no major height differences located in area. Terrain heights vary between 2 to 163 meters above mean sea level.

2 MATERIALS AND METHODS

2.1 InSAR DEM

InSAR data used in this study was captured during ERS-1/2 Tandem project. It was decided to use late autumn and wintertime image pairs in DEM generation to minimize the effect of forest. It has been proven by Dammert et al. (1998) that interferometric tree heights are smaller in lower temperatures. Precise Orbit (PRC) data was used in rectification of DEM's. Three image pairs were selected for DEM generation. Specifications of these image pairs are presented in table 3.

| Date | Orbit | Track | Frame | _ _ baseline |
|-------------|---------------|-------|-------|--------------|
| 19951014-15 | 22211 / 02538 | 179 | 2385 | 221m |
| 19960212-13 | 23943 / 04270 | 408 | 2385 | 87m |
| 19960302-03 | 24215 / 04542 | 179 | 2385 | 76 |

Table 3. Selected image pairs for DEM generation.

DEM generation was carried out by Novosat Oy, using SarDEM software generated in co-operation by Remote Sensing Group of Technical Research Center of Finland in co-operation with former Satellite Image Center of National Land survey (NLS) nowadays Novosat Oy. Three separate DEM's and a mosaic of these were produced. Coherence was used as a weighting factor in DEM mosaicking. Spatial resolution was set to 20 meters. From wintertime images water bodies with ice and snow cover were phase unwrapped. Test area included approximately 30 lakes, which were visually interpreted and outlined. It was noticed that areas as far as 700 meters from coastlines could be interpreted to include in water body. Heights over water bodies were calculated as a perimeter mean of outlined water body. Large number of phase unwrapped water bodies can cause work to be quite time consuming.

Difference images were calculated between InSAR DEM's and reference DEM. Root mean square (rms) error was used to study accuracy of InSAR DEM.

2.2 Morphographic map

Morphographic map was produced from multispectral satellite image using common pattern recognition methods, ISODATA clustering and maximum likelihood classifier. ISODATA clustering was used to create class signatures for classification process. Maximum likelihood algorithm was used to classify the image. Generated map was compared pixel by pixel to reference map. Error matrix and different accuracy values were computed. Build-up areas are more difficult to classify correctly from multispectral image. It was decided to interpret build-up classes visually from the panchromatic image.

2.2.1 Multispectral image. Landsat 5 TM image was selected for morphographic map generation. TM images cover large areas (180kmx180km) with reasonable spatial resolution (30m) for medium scaled morphographic map. Selected TM scene was captured in late summer 27.08.1997. In august annually differences between period of growth have even out making classification more reliable.

TM image was rectified to Finnish co-ordinate system using topographic map in scale 1:20,000 produced by National Land Survey (NLS) as a reference map. Rectification was done using second degree polynomial rectification algorithm with twenty ground control points (GCP's). GCP's were selected from the edges of image with additional points in the center of the image. In the rectification process TM image was also re-sampled to correspond to 20 meters pixel size. Cubic convolution method was used in re-sampling process. Because, the test area has no major height differences ortho-correction was not considered necessity.

2.3 Road network

Road network was visually interpreted from panchromatic image.

2.3.1 Panchromatic image. Road network interpretation and updating was done from the IRS-1C panchromatic image. Selected image was captured in 6.10.1998.

In the pre-processing stage image was rectified to Finnish co-ordinate system using basic maps of Finland. There are no major height differences on the test area so ortho-correcting was not considered necessity. Image was re-sampled to five-meter pixel size using cubic convolution method. To improve interpretability contrast stretching was applied.

2.4 Reference materials

2.4.1 Reference DEM. Reference material for InSAR DEM accuracy assessment was the DEM25 produced by NLS. The overall accuracy of DEM is estimated to be 1.76 meters. Accuracy over test area is estimated to be better than five meters. Pixel size of DEM25 is originally 25 meters, it was re-sampled to 20 meters pixel to equal the pixel size of produced InSAR DEM.

2.4.2 Morphographic map. Reference material for morphographic map accuracy assessment was the digital land use and forest map produced by NLS. The original land use map contains a large number of different land use classes, approximately 50 different classes. These classes were combined to produce land use map containing classes required in this study. Reference map classes are area based, where smaller details have been filtered out. It was noticed that reference map was out of date in some areas in this fast growing urban area. Reference map was up dated from digital ortho-photographs of area. Reference map included narrow streams and rivers, which were not interpretable from TM image. These streams and rivers were filtered out.

2.4.3 Road network. For the road network accuracy assessment there was the NLS's road database in scale 1:20000. Road database is updated once in every year. This database includes twelve different road classes. These classes were combined and some classes were dropped to produce the classes required.

3 RESULTS

3.1 InSAR DEM

Rms errors over each InSAR DEM were calculated. Results are presented in table 4. Maximum errors of each InSAR DEM are quite large. Maximum errors are located in sandpit near city of Hyvinkää. This area was presented as hill in DEM25, leading to quite large differences.

| InSAR DEM | RMSE | Std | Max error |
|-------------|-------|-------|-----------|
| Mosaic DEM | 3.29 | 2.813 | 46 |
| 19951014-15 | 6.482 | 4.86 | 62 |
| 19960212-13 | 7.472 | 6.121 | 101 |
| 19960302-03 | 5.109 | 3.959 | 67 |

Table 4. Rms errors over test area.

Some type of weather phenomenon was present during acquisition of image pair 19951014-15. This can be noticed from difference image as waves with 3 to 5 kilometers wavelength. In this type of case image pair should be replaced with other image pair.

Digital land use map was used to study the effect of different land use types to the accuracy of InSAR DEM. Forested areas were divided to three different classes according to forest density. Forest class 1 included areas < 50 m³/ha forest class 2 included areas 50 - 150 m³/ha and forest class 3 included areas > 150 m³/ha. Build-up area definitions are the same as in table 2. Results are presented in figure 1.

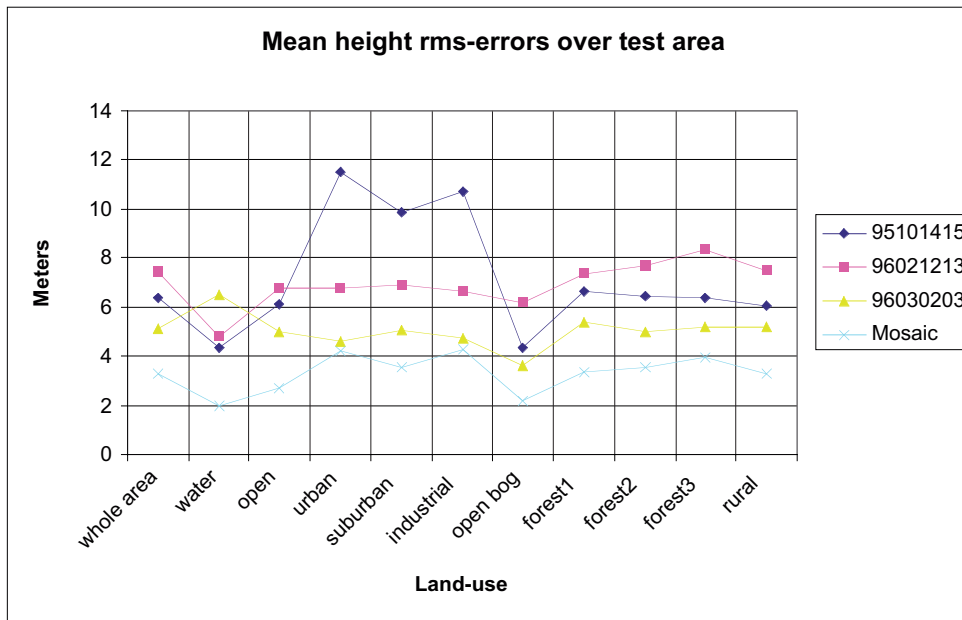
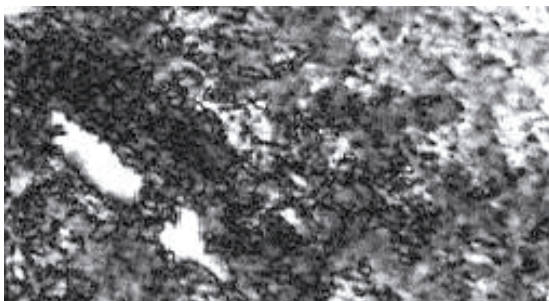


Figure 1. Rms errors in different land use classes.

The effect of different types of objects, like trees and buildings, on the ground can be seen. These effects can be corrected mosaicking multiple image pairs over same area.



Difference images were compared with IRS-1C panchromatic image, Landsat TM image and digital land use map. It was found out that some differences can be explained by change of terrain since generation of the reference model. Recently dug sandpits cause height differences around 15 to 30 meters comparing to the reference model. Example of this is presented in figure 2. These facts indicate that produced InSAR DEM can be considered at least in some parts more

accurate than the reference model. During visual study some errors were found from

reference DEM. Heights of some water bodies were bigger than in surrounding land.

Figure 2. Two sand pits are seen as white areas in root square image.

3.2 Morphographic map

3.2.1 Information extraction. To generate re-organized information and improve classification results, new bands were generated arithmetically combining original spectral bands. An advantage of these different ratio images is that they extract and emphasis differences in spectral reflectance of materials. A disadvantage of ratio images is that they suppress differences in albedo. Another disadvantage is that any noise is emphasized in ratio images. (Sabins 1997)

Principal component (PC) images were computed to concentrate image information into reduced number of bands. Normalized vegetation (NDVI) and brightness (BI) indices were calculated.

$$\text{NDVI} = (\text{TM4} - \text{TM3}) / (\text{TM3} + \text{TM4}) \quad (1)$$

$$\text{BI} = \text{Rootsquare} (\text{TM3}^2 + \text{TM4}^2) \quad (2)$$

Signature separability was studied in order to choose best band combination for classification. Transformed divergence was used separability measure. Band combination presented by Mas et al (1996) was used in classification. Two first principal components, NDVI and BI were used in morphographic classification.

3.2.2 Classification result. Interpreted build-up areas were combined with classification result. Resulted morphographic map was compared with reference map pixel by pixel. Error matrix was generated from this comparison. User's accuracy (UA), producer's accuracy (PA) and overall accuracy were computed from error matrix. Producers accuracy is computed by dividing correctly classified pixels in each class by number of training set pixels used for that class. It indicates how well reference data pixels of class are classified. User's accuracy is computed by dividing number of correctly classified pixels in each class by total number of pixels that were classified to that class. It indicates probability that pixel classified to a class actually represents that class. Overall accuracy (OA) is computed by dividing the total number of correctly classified pixels by total number of reference pixels. (Lillesand et al 1994)

Neighborhood based 3*3 filter was used to drop smaller details from classification result to improve correspondence of classification result and reference map. Original and filtered classification results are presented in table 5. Water is usually the most interpretable class. Test area included few shallow ponds, which were classified as forest. This reduced total accuracy of class water. Class rural was classified quite poorly. Visual interpretation of panchromatic images could be used to improve results. Goal to reach 90% overall accuracy was not met. Although, results can be considered quite good keeping in mind that reference map is not error free.

| Class | Pixel based result | | Filtered result | |
|------------|--------------------|--------|-----------------|--------|
| | UA (%) | PA (%) | UA (%) | PA (%) |
| Water | 77.12 | 19.86 | 84.33 | 53.43 |
| Open | 69.70 | 77.94 | 74.89 | 79.81 |
| Forest | 79.92 | 80.87 | 83.78 | 82.87 |
| Rural | 39.85 | 31.94 | 41.67 | 31.44 |
| Industrial | 78.35 | 80.82 | 78.15 | 86.37 |
| Sub-urban | 78.63 | 73.29 | 77.52 | 85.59 |
| Urban | 79.50 | 79.71 | 78.37 | 90.80 |
| | OA (%):71.51 | | OA (%): 76.42 | |

Table 5. Classification results.

3.3 Road network

The road network over the whole test area was produced. This was compared with roads from road database. Visual review of success of interpretation was done. All of the dual lane roads were easily interpreted. Few roads in classes federal highways and connecting roads were confused with each other. From these quite new urban settlements main streets were easily interpreted. Quite complete street networks can be interpreted from these type of urban areas.

4 CONCLUSIONS

Results from this test site correspond quite well to the requirements set for data accuracy. Height accuracy of single image pair would be sufficient to produce DEM with 50 meters pixel size in this type of terrain. Two or more image pairs would be needed to produce DEM with 20 meters pixel size. Medium scale morphographic maps covering large areas can be successfully generated from Landsat TM images. Visual interpretation of build up areas is required for accurate urban classification.

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REFERENCES

- Dammert, P., Askne, J., 1998. Interferometric tree height observations in the boreal forests with SAR Interferometry, IEEE International Geoscience and Remote Sensing Symposium Proceedings, vol3, pp. 1363-1366.
- Lillesand T.M., Kiefer R.W., 1994. Remote Sensing and Image Interpretation. John Wiley & Son, Inc.
- Mas, Jean-Francois and Ramirez, Isabel 1996. Comparison of Land Use Classifications Obtained by Visual Interpretation and Digital Processing. ITC Journal 3/4 1996.
- Sabins, Floyd F. 1997. Remote Sensing principles and interpretation. W.H. Freeman Company. Third edition 1997.
- Tiihonen, E., 1997. Geographical Information and its Quality in Radio Network Planning. Master's Thesis, Department of Surveying, Helsinki University of Technology.
- Zebker, H.A., Werner, C.L., Rosen, P.A., 1994. Accuracy of Topographic Maps derived from ERS-1 Interferometric Radar, IEEE Transactions on Geoscience and Remote Sensing, vol. 32, pp 823-836.