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Application of Digital Photogrammetric Products for Cellular Radio Network Planning

ECKHARD SIEBE and ULRICH BÜNING, Düsseldorf

ABSTRACT

Mannesmann Mobilfunk GmbH with its D2 network is the first private GSM network operator in Germany. This paper informs about the use of digital photogrammetric products in the radio planning process of the Public Land Mobile Network "D2 privat". For generating land use, terrain elevation and city structure data, photogrammetric and remote sensing techniques will be used. Mannesmann Mobilfunk's activities in this field, the different data products and their requirements are described.

1. INTRODUCTION

The D2 Privat network is operated by Mannesmann Mobilfunk and is based on the GSM (Global System for Mobile Communication) standard. Currently, more than 2.5 million customers use the D2 network with its voice, data and international roaming services. To meet the requirements of its customers, Mannesmann Mobilfunk sees the radio planning process as a key part in the network development and optimization. One result of the radio planning process is the assignment of the limited resource frequencies. The whole radio planning process is computer based. Therefore a digital model of the real world is used. Part of this model of the real world consists of digital photogrammetric products.

2. RADIO PLANNING IN A CELLULAR NETWORK

The objective of mobile communication is to establish every time and everywhere a connection to a subscriber of a public network and to hold this connection without interruption. The GSM standard has adopted 124 carriers for most countries in the 900 MHz domain. Each carrier consists of two frequency channels with a bandwidth of 200 Khz in an upper and a lower band. The upper band establishes the downlink (from the base station to the mobile) and the lower band the uplink (from the mobile to the base station). Every frequency channel is devided in eight time slots. Therefore GSM belongs to the category of the TDMA systems (TDMA Time Division Multiple Access). In Germany the 124 frequency carriers are shared between two operators. So each operator, DeTeMobil (D1) and Mannesmann Mobilfunk (D2), can use 62 carriers.
In a cellular system a fixed base transceiver station (BTS) covers a spatial limited region. A mobile in this region will be connected to this base transceiver station. The handover from one cell to another cell is transparent to the customer. Signalling and switching intelligence in the network and the mobiles enables this handover.
A cellular system can be adopted to the coverage and capacity demands of the market by the network operator.
An example for coverage demands of the market is the growing use of hand-held phones. These mobiles have very low transmission power (2 watt). The spatial limits (coverage) of a cell depend mainly on the physical parameters, radio transmission power and the topography with relevance for electro magnetic waves in the specific frequency domain. Adding new cells allows the use of mobiles in places, where formerly only car-based mobiles with transmission power of 8 watt could be used.
An example for capacity demands of the market is the growing use of mobiles in the so called hot spot regions. With a cellular system these demands can be met by decreasing the cell sites (reducing transmission power in the base station) and adding new small cells. For example, a service region like

Cologne is covered by one cell (comparable to an UKW-radio station). If all GSM channels available for one operator are linked to this BTS, ca. 490 customers can have a connection at the same time. This would result in blocked customers, because more than 490 customers are asking for service in this region. If the same region is covered by 100 cells and every cell has 2 channels, than ca. 1600 customer can have a connection at the same time. With only 62 frequencies available it is necessary to use multiple frequencies in this region. To meet the interference effects, a good knowledge of the potential interference situation is necessary. If the network operator knows where strong interference potential will be, he can use procedures for an optimized frequency reuse assignment and thus avoid interference problems.
The above-mentioned examples show the potential of cellular systems to meet the coverage and capacity demands of the market. To realize these adoptions, it is necessary to have a good planning process. The investment in changing and adding cell sites is enormous. Mannesmann Mobilfunk invested approximately 750 Million DM in 1996 in expanding the D2 network.
Nevertheless the cell adoption has limits to meet capacity demands and other methods or technologies are necessary. Because GSM is a digital system, technologies like power control, frequency hopping and new speech coding procedures are being or will be introduced.

3. IT-BASE FOR THE RADIO PLANNING

For a cellular network like 'D2 Privat' an economic planning is not possible without the use of information technologies. The D2 network operates currently approx. 9000 cells all over Germany. The handling of such dimensions for planning purposes is only possible with computer based processes. To simulate the radio part of the network, complex physical models are implemented in special software tools. These models require a digital description of the real world, that has relevance to the 900 MHz electromagnetic waves: land use data, building data, terrain elevation data, demographic data, traffic network data and topographic maps.
The data resolution, or better the information density, is proportionally inverse to the cell size. The great amount of data and processing capacity requires computer systems with scale up client-server architecture.

4. GEOGRAPHIC DATA FOR THE RADIO PLANNING

Within the radio planning process different data sets with geographic reference are used. These are e.g. digital topographic maps of different scales, demographic data and traffic network data. In the following some data sets with reference to photogrammetric and other remote sensing methods will be introduced.

4.1 Coarse terrain elevation data

The radio network planning process extends to the entire area of Germany. This leads to the request of a great amount of data. For hardware, storage, economic and calculation aspects the terrain data is geocoded and 100m raster-based for the entire area of Germany including a 70 km strip of the neighboring countries, in total an area of 640 000 km^2. The data is generated either by cooperation with the Surveying and Mapping agencies in Germany, by placing orders or by purchase. The partly inhomogeneous data sets are combined to a final result (figure 1), in summary the parameter of the data are:

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- $100 \times 100\ m^2$ grid
- altimetric accuracy ± 5-10 m
- geographic reference Gauß-Krüger strip 3 and 4
- altimetric reference NN

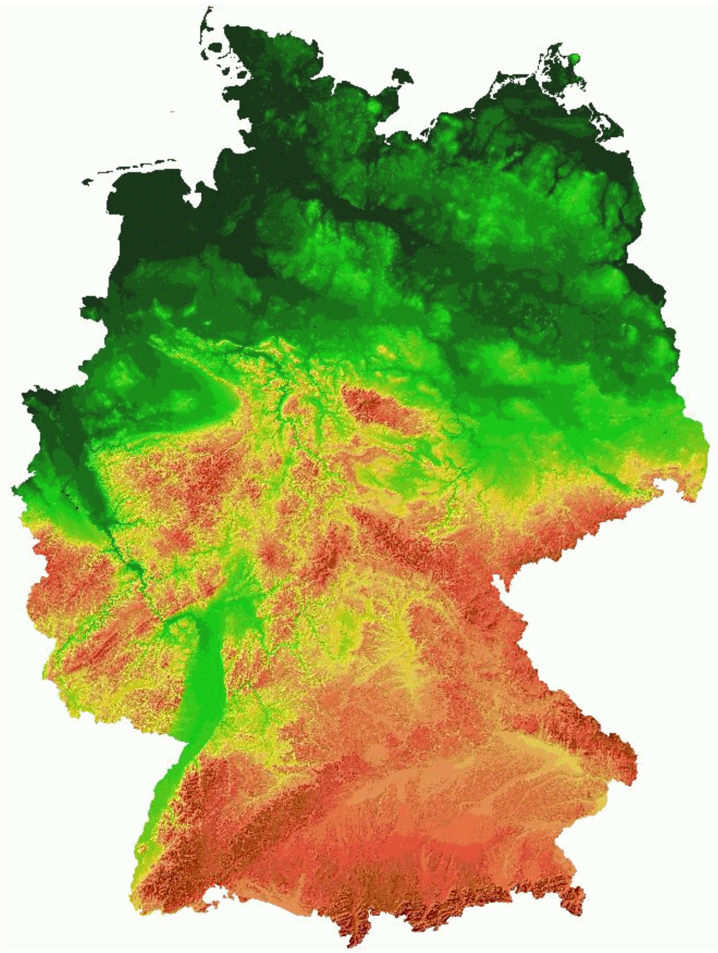

Figure 1: Terrain elevation data of Germany.

Problems caused by different generation procedures (e.g. photogrammetric profile measurements in the state of Baden-Württemberg including vegetation height) and by the official update cycle lead currently to a study. Hereby the potential of spaceborn radar sensors for detecting errors in the elevation data and in the land use data will be explored.

4.2 Land use data

The different types of land use cause different propagation loss of electro magnetic waves. Based on Landsat TM - multispectral data a classification was carried out. The scenes are dated between 1990 and 1993. By using a supervised multispectral classification, 7 main classes and 9 subclasses were classified. The different scenes were geocoded and mosaicked, the output raster size is $25m^2$, the data is used within the propagation model in minor sizes. Figure 2 gives an impression of the land use data.

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Figure 2: Land use data of Germany.

The parameter can be summarized as:

- 16-class land use (main classes: urban, forest, agriculture, paved areas, water, opencast mining, glacier)
- 25 x 25 m^2 grid
- accuracy 90% correct classified pixels in the main classes
- geographic reference Gauß-Krüger strip 3 and 4

Currently some tests concerning update problems are being carried out with both up-to-date Landsat TM data and with radar data as mentioned above.

4.3 3D - City Structure data

As mentioned above the demand for increasing capacity in the hot spot regions is tremendous. The introduction of smaller cell sites is a possibility, however because of the multiple use of frequencies and thus causing interference the precise knowledge of the antenna locations and their surrounding topography is very important for the frequency reuse assignment.
As a city structure model we define geocoded digital elevation data in urban areas including the heights of buildings, but (at least up to now) without other information (e.g. vegetation).
These types of data were not available, so Mannesmann Mobilfunk placed some orders for it to be generated. Some feasibility tests were carried out in advance in order to define the methods, the requirements and the practicability. However the requirements have to be seen in the background of using the data in the environment of radio network planning tools with the input of many different data sets and their mutual dependence. Further criteria are the costs, completeness, up-to-dateness, delivery time, reliability and accuracy.

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The buildings are generated as boxes with flat roofs (with the highest representative point as reference), the minimum planimetric area is 50 m^2, the minimum height is 3 m above ground. The final pixel size in the raster data sets is 5x5 m^2, the planimetric accuracy is ± 2.5 m, the vertical accuracy ± 2 m.
In summary the content of the city structure data is as follows:

- the elevation model in raster format
- the building model in raster format
- the combined building and elevation model in raster format
- the building model in vector format
- digitalization of the aerial images with 25 µm
- generation of a digital orthoimage mosaic with a pixel size of 0.5 m

Figure 3 shows a perspective view the of downtown Frankfurt and demonstrates the quality of the model.

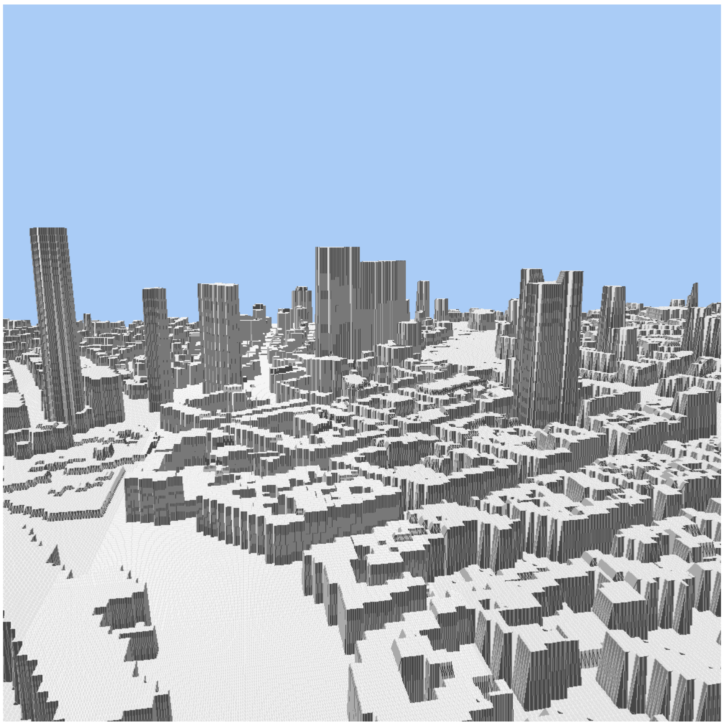

Figure 3: Perspective view of downtown Frankfurt.

Photogrammetric methods proved to be most appropriate to generate the data. Up to now more than 20 German cities and metropolitan areas with more than 3.500 km^2 are available to Mannesmann Mobilfunk. The data is generated by classical analytical methods or by semi-automatic procedures including GIS procedures. Using the semi-automatic method the heights of buildings and terrain are determined by correlation procedures, however the extraction of building outlines is still critical and can only be done reliably by human operators. As long as this issue is not solved the digital methods will not be headed above the classical approach.
As mentioned above, the data model used is not fixed. Currently the propagation model will be expanded in terms of using the original generated vector data (instead of raster) and vegetation information. Tests with different databases are carried out. Within a diploma thesis the detection of trees in aerial images by using image segmentation and neural networks was examined. The first results delivered were promising.
Another important issue is the problem of controlling and updating the datasets. The present data comprises more than one million (building) polygons, that have to be checked and improved if

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necessary. We are still looking for procedures for detecting building activities on the one hand and for the economical updating of the changes on the other hand. In this context we are currently observing radar methods as an alternative (also with regard to the limited time of appropriate flight conditions for aerial images).

5. CONCLUSIONS

The planning process of cellular radio networks needs various digital geographic data. The growing number of customers in conjunction with growing capacity demands lead to requirements of using data with high resolution. 100m and 200m based raster data in rural areas will be complemented more and more by 5m- based data in urban areas. Currently the propagation models will be advanced in terms of using vector data. The great amount of required data and their various types offer challenges to both industry and research. Because the main stock of data has been derived, emphasis must be laid on controlling the data and keeping the data up-to-date. Remote sensing techniques like radar and the new developments of high resolution scanners will hopefully support this task just as further developments on the field of semi automatic building extraction models. Mannesmann Mobilfunk is observing and supporting these activities.

6. REFERENCES

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