CONTROLLING AND UPDATING OF 3D - URBAN DATA WITHIN A DIGITAL PHOTOGRAMMETRIC WORKSTATION

Peter Kempa
Eckhard Siebe
Mannesmann Mobilfunk GmbH
D - 40543 Düsseldorf, Germany
e-mail: pkempa@tegate.mmo.de
e-mail: esiebe@tegate.mmo.de

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ABSTRACT:

Mannesmann Mobilfunk GmbH with its D2 network is the first private GSM network operator in Germany. The D2 network is a cellular radio network with small cellular sites. For planning cellular radio networks topographic data will be used. This includes demographic data, the information about the landuse and, most importantly, accurate terrain height data. Especially in the major cities the topographic data which has been used up to now is no longer sufficient. Not only the terrain hights are needed, but the knowledge of the city structure itself is a presumption for the planning of further antenna locations for the so-called microcells.
City structure data is defined as geocoded terrain height data including the location and the height of the buildings. This data is not yet available, so it was derived by placing an order. Controlling of this so derived data, which is the major problem, is going to be discussed and possible methods of updating are presented.

KURZFASSUNG:

Die Mannesmann Mobilfunk GmbH ist der erste private GSM-Netzbetreiber in der Bundesrepublik Deutschland. Das D2-Netz ist ein zellulares Funktnetz, das sehr kleinmaschig konzipiert wurde. Für die Planung zellularer Funknetze werden unter anderem topographische Daten benötigt. Dazu gehören neben den Informationen über die Geländenutzung und den demographischen Daten insbesondere die Informationen über die Geländehöhe. Für den weiteren Ausbau des digitalen D2-Mobilfunknetzes in den Städten reichen die bisherigen Kenntnisse über die tatsächliche Geländeoberfläche nicht mehr aus. Neben der reinen Geländehöhe ist die Kenntniss über die Stadtstruktur selbst eine Voraussetzung für die Planung von möglichen Antennenstandorten für die Mikrozellen.
Ein digitales Stadtmodell ist als eine geocodierte, höhenmäßige Darstellung einer Stadtoberfläche zu verstehen. Die Höhendarstellung umfaßt dabei nicht nur die Darstellung der physikalischen Erdoberfläche, sondern zusätzlich noch die Darstellung der Gebäude. Da diese Art Daten derzeit am Markt nicht erhältlich sind, wurden sie im Auftrag erzeugt. Zunächst soll die Kontrolle der so gewonnenen Daten, die ein Problem darstellt diskutiert werden und anschließend wird ein Ausblick auf die Möglichkeiten der Datenaktualisierung gegeben.

1. INTRODUCTION

In December 1989, the "Go Ahead!" signal was given for D2 privat when the Minister of Posts and Telecommunication awarded Mannesmann Mobilfunk the licence to operate the first private digital mobile telecommunication network in Germany. The D2 network is based on the GSM-standards (Global Systems for Mobile Communication). This standard creates uniform guidelines for the digital mobile radio communications and allows cross-border roaming throughout Europe. As a result of this joint standard, it was possible to create a uniform infrastucture as the basis for a pan-European mobile communication market.
Today Mannesmann Mobilfunk has approximately 2,800 employees throughout Germany. The D2 network covers more than 98% of its citizens and 95% of the area.
The D2 network is a cellular radio network with small cellular sites. Each cell has a Base Transceiver Station (BTS) which establishes the connection to and from the subscribers. The size of a cell depends on the surface and the expected traffic load, and on the performance of the base and the mobile stations. The radius of a cell variies between one and thirty kilometers. For computer based planning of cellular radio networks geographic data will be used. This includes demographic data, the information about the landuse and most importantly terrain height data. Terrain height data is geocoded within a 100 m grid. The accuracy of the supporting points is ± 5 m.
This data is one of the parameters needed for the the calculation of the field-strength, which is the base for further planning steps. The results of the planning process are optimized locations for the base stations, the relevant initial parameters and the frequencies of each base station to serve a region with sufficient quality and capacity.

2. MICROCELL PLANNING

Due to the growth of the subscribers of the D2 network, the resulting high traffic load and the use of low performance mobile phones the network has to be adjusted continuously. One possibility of expanding the capacity, that is to say more subscribers are able to set up calls at the same time, is the introduction of smaller cells with their own BTS. The capacity (Erlang/km^2) is proportional to the number of cells within a specified area.

The growing number of cells (and BTS) leads to a problem however. Each BTS uses a specified frequency for the connection to and from the mobile. The number of possible frequencies is limited however, therefore each frequency has to be used as often as possible. On the other hand the same frequencies sent from different BTS must not disturb each other to avoid interference problems and dropped calls. Therefore the knowledge of the topography is very important.

Especially in the major cities the topographic data (100 m by 100 m pixelsize) which has been used up to now is no longer sufficient. In order to plan optimized coverage and capacity precise digital data of the terrain height including the location and the height of the buildings (city structure data) are currently needed. The knowledge of city structures is a presumption for the planning of further antenna locations for the microcells. The height above ground of these antennas will not project neighboring buildings and the coverage performance of a microcell will be within a radius of one kilometer.

For modelling the urban areas sophisticated fieldstrength propagation models have been developed. Mannesmann Mobilfunk is using the Urban-Micro-Model (Cichon et al., 1993), which describes multipath wave propagation by three components (vertical plane, transversal plane model and multipath scattering model caused by reflections). The computer-aided planning software bases on the use of precise raster data.

3. DIGITAL CITY STRUCTURE

To evaluate the requirements of the building data different procedures for providing data were initially tested and then subsequently the accuracy of the resulting data sets. A variety of different data sets were created from one testing site and others were aquired. These sets were compared with a regard to their usability with the prediction model currently used (Feistel, Baier 1995). This test resulted in the following data requirements:

- combined dataset of both terrain and building heights
- pixelsize of 5x5 m^2
- horizontal accuracy of about half pizelsize, vertical accuracy ± 2 m
- generation of all buildings with a larger size than 50 m^2 and above ground height of more than 3 m
- generation of the buildings as boxes with flat roofs (highest representative point)
- perpendicular rise of heights between ground and building (height discontinuity)
- division of building blocks into several parts, if the height differs by more than 3 m

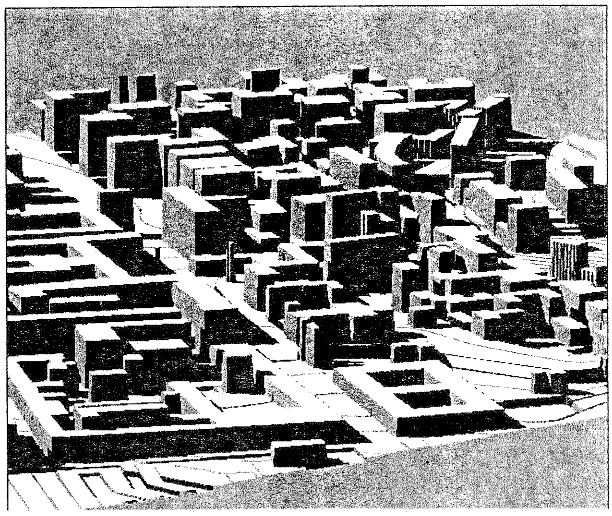

Fig.1: Digital model of a city

Moreover the data has to be generated or transformed to the same geocoded space as other data used at Mannesmann, that means Gauss-Kruger coordinates with Bessel ellipsoid and Potsdam datum, and they have to be transferable to the common used format within the company.

After establishing the prerequisites the first orders for obtaining the 3-D building data for several German cities were placed.

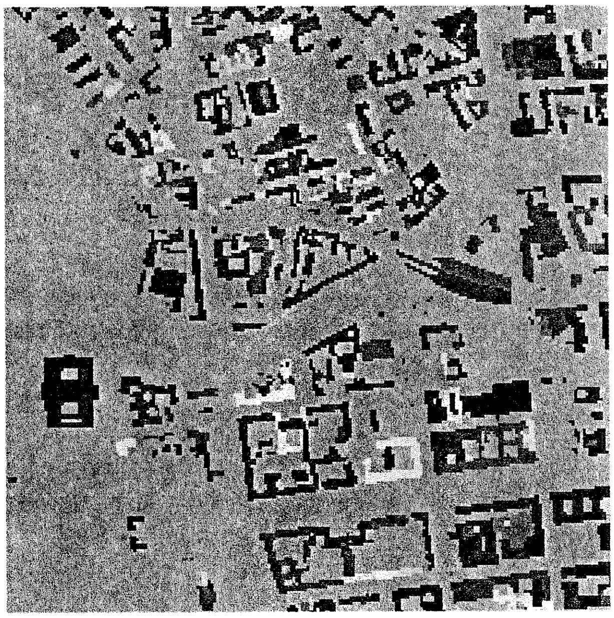

Fig. 2: Raster dataset of Berlin

4. HARD- AND SOFTWARE ENVIRONMENT

The planning of a cellular radio network is a very complex business that cannot be done without the extensive use of hard- and software. Within the headquarters planning department a huge UNIX-based network has been installed. Numerous SUN workstations are connected via FDDI or Ethernet. Different backup media like Jukeboxes, DAT and Exabyte are available. 2 Sparc Center 1000 for

central applications with a total of 90 GByte capacity enable the storage of all types of required data. Local connected disks with a total of about 80GByte storage capacity enable a fast planning. Different plotting systems (laser, electrostatic (up to A0), inkjet) are used for visualization purposes.
For controlling and updating the 3D building data a SPARCstation 20 with 2 60 MHZ SuperSPARC processors is used. 128 Mbyte of random access memory and for visualization a 24 bit graphic accelerator board and a 19" color display are available. For local storage a total of 27 Gbyte disk capacity can be used. The stereo environment is realized by connecting the StereoGraphics Crystal Eyes™ system containing an infrared emitter, stereo glasses and a controller.
For the various geographic applications the image processing and GIS tool ERDAS Imagine is used. In addition a perspective view module and a vector module (subset of the ARC/INFO package) are utilized.
Furthermore the Geographic Resources Analysis Support System (GRASS) is used. GRASS is a public domain, image processing and GIS package, written in C and developed by the U.S. army. It contains powerful raster functions and some vector functionality. The open software, that means all sourcecode is available, enables modification of the functions for the user-defined specifications.
The photogrammetric applications can be done by the OrthoMAX software package. It is a high performance softcopy terrain mapping and geopositioning package developed by Vision International, a division of Autometric, Inc.. The system provides capabilities of triangulation, stereoscopic viewing and mensuration, digital terrain model (DTM) extraction and editing and ortho rectification. The package is integrated into the ERDAS environment.

4. CONTROLLING THE DATASETS

3D building datasets of several German cities have been generated with the use of analytical and digital photogrammetric techniques by different companies. Due to the size of these areas (1000 km^2) and the density of buildings with different shapes (especially in the downtown areas) the controlling of the generated data is a major problem and can not be solved completely with manual methods. For this reason several control procedures have been developed. These procedures have to accomplish four major tasks:

- completness of the data
- position accuracy
- height accuracy and
- degree of specification (details of buildings)

4.1 Using GIS-techniques

In a pre-controlling process some special functions of the GIS package GRASS are used. These functions are usefull in finding rough errors. Instead of using a normal color ramp in displaying the data sets (fig. 3), the building dataset is displayed by a randomized color table. As can be seen in fig. 4 an unexpected edge can easily be detected by this visual method.

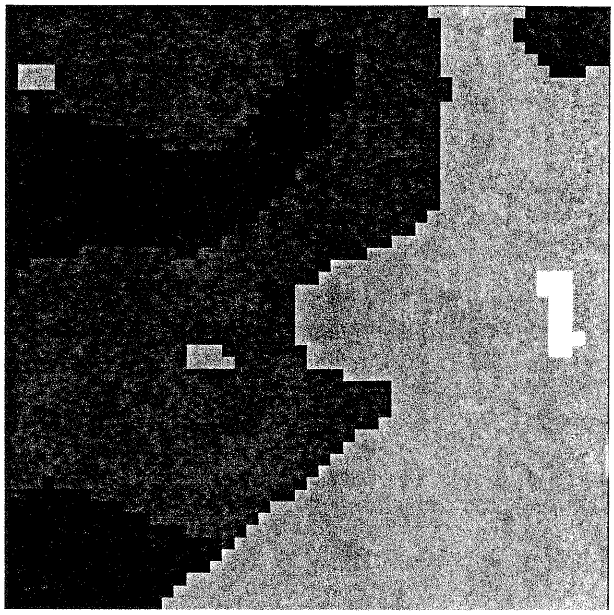

Fig. 3: Part of a digital city structure

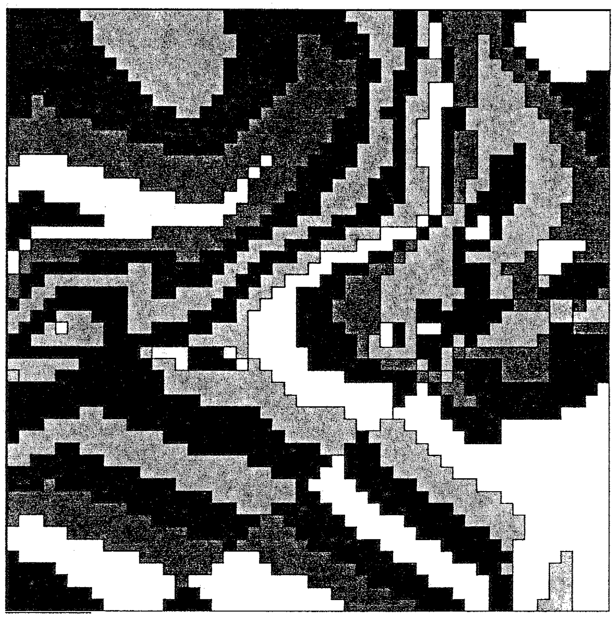

Fig. 4: Randomized color display of the same part

4.2 The digital photogrammetric workstation

For further controlling the image processing system ERDAS including the photogrammetric software ORTHOMAX is installed.
To check the completeness of the building layers initially an ortho-photo is made with the help of the digital area model from the aerial photograph. This dataset is projected to the building layers with a special overlay technique available in the ERDAS programme. With this blend and fade function it is posssible to accurately check whether the building location is correct.
Apart from the building datasets which are available in a 5 m raster, a vector dataset is created which should provide an area accuracy of 1 m. It is possible to check the site accuracy of individual buildings by overlaying the orthophotos with the vectors.

When placing the order it was specified at which particular height the buildings should be registered and with what degree of accuracy. As a result, a building that is higher than 3m and has a ground area of more than 50 m^2 should be registered as a single object. Parts of buildings that fulfil these requirements should also be treated as single objects.
In how far these details have been recognized can only be established with the vectors. These will be placed over the ortho-photos and can then be checked and compared visually.
The use of the photogrammetric software ORTHOMAX makes it possible to show stereopairs 3-dimensionally and to measure individual heights with a measuring scale. In this way individual building height can be determined. However, due to the data available, it is only possible to determine the building heights on a random basis.

4.3 Analytical vs digital photogrammetry

The composition of the digital building datasests is achieved by using two methods. On one hand conventional analytical methods were used, on the other the data was compiled with the help of the digital method. The digital stereo photogrammetric method differs compared to the analytical method because a number of processing steps run automatically.The most significant part hereby is the automatic correlation for determining 3-dimensional rasters with various degrees of density. Inspite of this, manual adjustments are still neccesssary, especially for the determination of the building outlines. That means that with both methods the quality of the building outlines (completeness, detail and area accuracy) largely depends on the individual engineer in charge. Examinations of the datasets show that the quality of the data does not vary significantly.
With the analytical method the determination of individual buildings heights is done by an engineer who establishes the building height by stereopair. It is the decision of the engineer at which particular points of the building's roof the measuring scale is set. Using the digital method, depending on the actual method used (middle value, maximum value), the height is determined by the area of the building from the raster (Guretzki, Erhardt 1996).
Due to the actual data available (approx. 60,000 single objects) the control of the building heights can only be established on a random basis. An engineer establishes individual building heights on the digital workstation and compares them with the height rasters. This leads to problems particularly when complex buildings are involved, because in the end it is also the decision of the engineer in charge at which point the measuring scale is set. An analysis of 100 height points using both methods shows that there is a variation up to 5 m in the set points established by the engineers. The standard deviation using the analytical methods is about 2 m, compared to about 3 m using the digital method. The accuracy level achieved is sufficient for the applications mentioned above.

5. UPDATING PROCESS

To use the building data in the microcell planning the actual status of the data is significant. Particularly in cities like Berlin where acute building activities are carried out, it is important to update the available datasets within very short periods of time. To make these updates possible a number of methods are available.

5.1 Regular aerial survey

The most accurate method of updating the data is regular aerial surveys. However, as the microcell planning is steadily on the increase, it will become necessary to obtain building data for other cities so that a complete analysis of already existing city data would considerably exceed the permitted cost budget. A complete internal evaluation of the data within the office is not possible due to a lack of resources. House internal surveys can only be limited to smaller areas whereby the question arises as to which areas should actually be updated.
In some branch offices of Mannesmann Mobilfunk regular evaluation journeys are made to determine the field-strength available. All engineers involved possess exact knowledge of the situation in the individual cities. This information should be used to evaluate part areas. If contemporary aerial survey data is available for a particular area this should be obtained, otherwise aerial survey flights have to be initiated. For these small areas involved a subsequent in-house-evaluation can be carried out with the existing photogrammetric workstation.

5.2 Use of other data

A further possibility is the use of already available digital data. Most local construction offices are already in the process of using digital data for administration purposes. By enquiring regularly at the construction offices areas with a high level of building activities can be identified and updated if required.

6. SUMMARY

At present controls of 3D-buildings can only be carried out manually. The possiblity to use photogrammetric worstations provides a great help in accomplishing this task. However, there still remains the need to have a more automated process. The same applies for the updating process. Here as well things can only be achieved by a higher engagement of engineers and resources.

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