STRATEGIES FOR UPDATING A NATIONAL 3-D TOPOGRAPHIC DATABASE AND RELATED GEOINFORMATION

P. Frederiksen, J. Grum, L.T. Joergensen

National Survey and Cadastre – Denmark, Rentemestervej 8, DK-2400 Copenhagen NV, Denmark
(pof, jrg, ltj)@kms.dk

Inter-Commission WG II/IV

KEY WORDS: Photogrammetry, Topographic Databases, Revision, Production, Infrastructure, DEM/DTM

ABSTRACT:

A national topographic database for Denmark was established during the 1990'ies and completed at the end of year 2000. The database comprises three components: A 3-D vector database with full topology, a database with names of places and points of interest and an elevation database.
This paper is about the revision and maintenance of the databases.
The vector geometry was captured photogrammetrically. The update takes place in a 5 years cycle, i.e. 20% of the country is revised every year according to detailed specifications. Due to user needs focus is now on administrative revision in order to update specific object types with a higher frequency than 5 years. Roads, road names, hydrographical networks and building are of special interest for the geo-data infrastructure.
The origin of the database for place names and points of interest goes back to the 1970'ies. It is maintained by an extensive use of sources in the public and private sectors utilising the Internet. It's a dynamic process where new sources are identified frequently and agreements concluded with the data providers.
The third database component, the elevation model, is based on digitised contours and heights from selected objects from the 3-D vector database. Spot heights, i.e. maximum and minimum elevation points, measured in connection with the photogrammetric revision of vector data are also included. Heights in the elevation model are estimated by a data fusion approach considering characteristics of the individual data points. Data is stored in a grid structure and as computed contours.

1. INTRODUCTION

The topographical mapping in Denmark (scale 1:10.000 and smaller) is the responsibility of the National Survey and Cadastre (KMS) - an institution under the Ministry of the Environment.

In 1995 the TOP10DK topographical database was defined. The abbreviation TOP10DK is the synonym of the topographical database with the reference scale 1:10.000 in Denmark. The geometrical part was established during the late nineties by photogrammetry.

Since then the TOP10DK has developed into a concept comprising a number of more or less integrated databases.
The more important databases are:

- The database holding geometry of objects
- The database for place names and points of interest (POI)
- The elevation database

Conceptually, TOP10DK also holds a separate road network database.

The TOP10DK was completed covering the entire country at the end of year 2000. Since then the task has been to develop and implement a revision strategy.

2. CONCEPT OF THE TOPOGRAPHICAL DATABASES

The objective was to establish one single topographical database where data should be collected only once, stored and updated. Data redundancies should be avoided as much as possible. From this database all other application databases should be derived.

The derived databases are defined from the degree of details in the data rather than a specific scale factor. The degree of details implies

- A list of objects in each derived database
- Corresponding generalisation specification.
- Scale interval for proper use of data

From the derived databases thematic maps, data for GIS purposes, printed maps or data specifically meant for screen maps in Internet services are extracted.

It is crucial that all updates are stored in the TOP10DK databases, i.e. geometry, heights as well as POI and names.

3. GEOMETRY

3.1 Geometry Characteristics

The geometry part of the database includes 51 object types subdivided into 8 object classes - all described in details in the

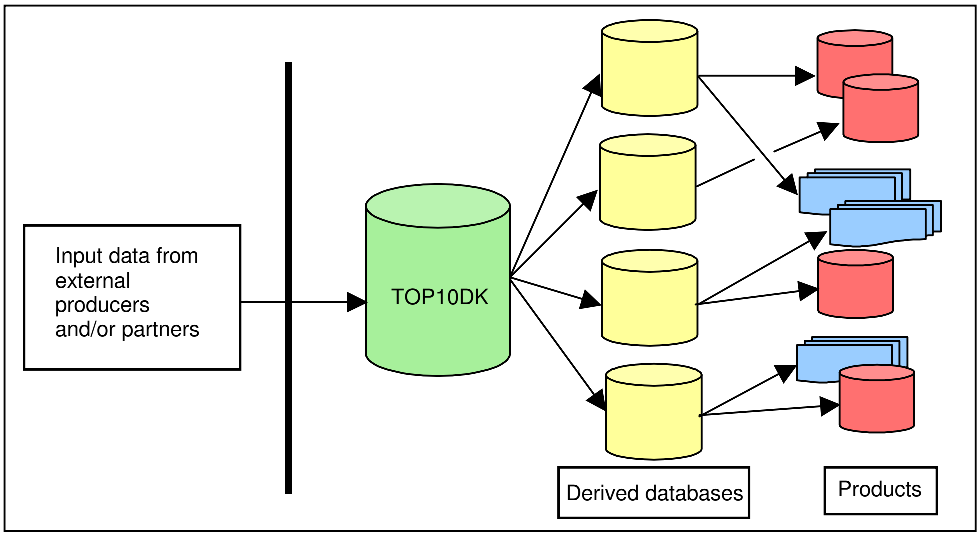

Figure 1. The TOP10DK database, derived databases corresponding to various degrees of detail and final output as digital or analogue products

TOP10DK geometry specification. The specification is updated frequently in order to meet new user requirements.

In general, the geometrical accuracy specification is 1 meter in all three co-ordinates, but in well-defined object points the accuracy is significantly better. It is a 3 D (2½ D) database with a data model claiming strong requirements on completeness and on both 2D and 3D topology.

The geometry is based on photogrammetric registration from 1:25.000 scale aerial photos. The revision cycle is laid out to 5 years, i.e. 20% of the country is revised every year.

When the database was established all photo points were defined a priori in a regular pattern and an aerotriangulation was measured and computed. The same photo points are aimed at when the photo flights for revisions are planned for subsequent years. In this way the photogrammetric models are located approximately at the same positions and tie points and geodetic points from the database establishing can be reused. GPS technology makes it possible to take the photos at the right position within 50 meters.

.

Approximately 1.500 photos are taken per year. Since digital photogrammetry is the dominating production method all images are scanned. A resolution of 21 μ has proved sufficient for revision purposes.

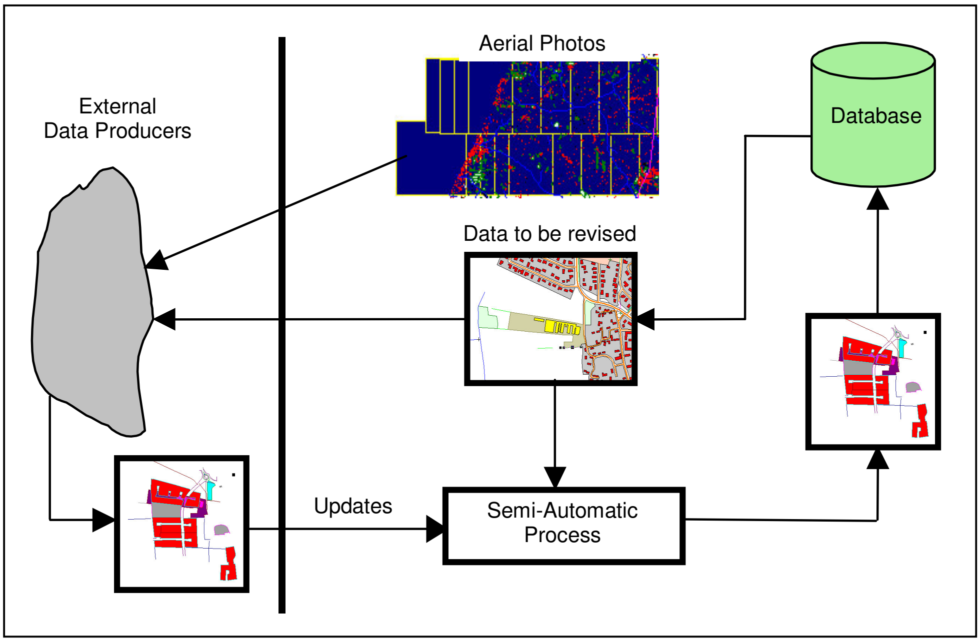

Figure 2. Dataflow for the revision process (after Hoejholt 2004)

3.2 Revision strategy

The TOP10DK concept is based on outsourcing. However, all planning, certain control procedures and the final database updates are done in-house. The companies that are to carry out the photography, the image scanning and the revision process are selected from separate tenders. Normally, 5 - 10 bids are received within each category.

The heavy part is the revision of the geometry. The area in question per year is approximately 10.000 km^2, which is subdivided into 6 – 10 stages. 3 – 4 photogrammetric companies share the total revision task.

The companies are provided with all necessary material from KMS including a copy of the existing database and software developed for the in-house control phase (Kamper, 2004). The idea behind is, that the data producers can run a number of the automatic control procedures themselves checking for topology, network consistency etc.

The revision is based on incremental updates, i.e. only changes are registered and received at KMS as +/- data. New objects are measured photogrammetrically and objects that no longer exist are deleted. Changes in geometry of existing objects are dealt with in two different ways. Small objects with significant changes are erased and replaced by a new registration (object +/- data). For bigger objects, only changes are registered and added or subtracted from the existing object (incremental +/- data). (Hoejholt et al., 1999)

All object points have attached registration information about instrument, image numbers, ground control point numbers etc.

In order to reduce the amount of written material, to avoid misunderstandings and to speed up the revision process a couple of Internet services have been introduced. All geodetic control points, corresponding sketches and co-ordinate lists are available through an Internet service. This year all ground control from the original aerotriangulation is also available through the Internet providing scanned images showing the positions of tie points from the aerotriangulation. The corresponding detailed and hand drawn sketches have been scanned as well and appear in the service together with co-ordinate lists (Figure 3).

An important revision trend is observed during the last few years. It is known as *administrative revision* where the information is received as temporary data from partners in the private or public sectors. An example is information on new or changed roads where the database is updated 3 times per year with preliminary information. The information is then confirmed by the 5 years revision cycle.

It is believed that this kind of information will become more and more important as the demands on topicality increase. An update strategy, where the information is received from an increasing number of partners and subcontractors with an increasing frequency.

4. COMMON OBJECT TYPES

Traditionally, topographical and large-scale mapping have been produced separately. This tradition has been inherited as regards the geo-spatial databases.

However, there is an increasing awareness about the fact that the some objects are recorded several times simultaneously but for different purposes or different customers. Important infrastructure objects are registered several times according to different specifications and stored in different databases.

Realizing this, the idea was born to define "common object types" (COT), i.e. object that are found in both topographical and large-scale databases. A specification for these objects is being prepared considering both the establishing and the revision processes. Examples of entities defined as COT are buildings, transport- and hydrographical networks, coastlines and administrative units.

In practice, COT are found in both databases while the

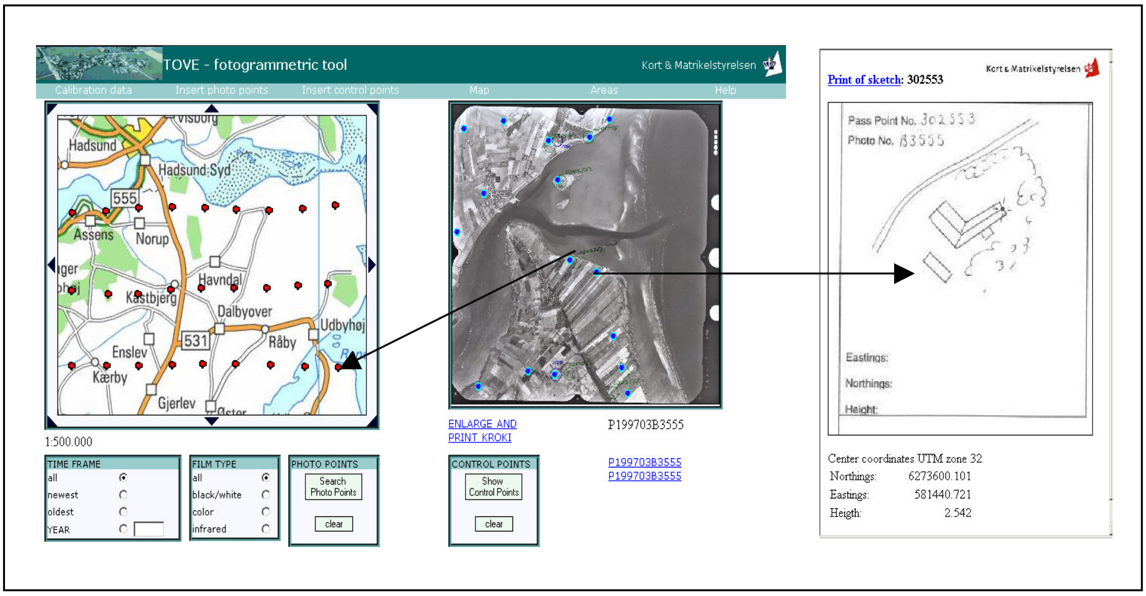

Figure 3. Internet service with ground control and point sketches for photogrammetric revision

remaining objects belonging to the topographical or the large-scale databases respectively are registered in accordance with the two basic specifications. On the long view, the full implementation of the COT concept will influence the specifications for both the topographical and the large-scale databases.

The COT are selected as being the most important objects as regards e-government and the spatial data infrastructure. A similar classification of objects is found in the INSPIRE initiative (European Environmental Agency, 2004), where administrative units, transport, hydrography etc. are defined as priority common basic data. Surprisingly, building are not found as basic data in the INSPIRE proposal but included as commonly used thematic data. However, buildings are considered extremely important and recorded in greater detail in Denmark and consequently included in COT.

5. PLACE NAMES AND POINTS OF INTEREST (SNSOR)

Names of cities, road names and POI are important information when geo-spatial data are in use, either on printed maps, as part of an Internet service or in GIS analyses. Accurate and up-to-date information on names and POI is crucial for Internet services such as travel planning, emergency turn out etc.

The TOP10DK concept comprises a separate database for place names and points of interest (SNSOR) that is closely linked to the geometry database. The SNSOR has become increasingly important as the demand for accurate and up-to-date information in Internet services is intensified.

5.1 Points of Interest

Points of interest are locations that are of general interest or locations that are of interest for a thematic visualisation of geo-data. Examples are museums, churches and railway stations as POI for general purposes or campsites on a map for recreational purposes.

The database is structured in such a way that a copy of the geometry, for instance the outline of a church is imported from the geometry base to the SNSOR database. Subsequently, the word “church” is attached to the centre of the building geometry. The physical placement, font, and size of the letters of “church” are decided during the visualisation process.

An automatic geo-coding process is introduced by defining an address point of the entity. It may be the centre of the building or it could be any point related to the surface defining the entity. Most information received from external sources is in one way or another related to the address of the entity. It is generally agreed that the address is one of the most important keys in the geo-coding process.

Received information from external providers is compared with an address register containing official addresses and corresponding locations, i.e. an address points (x, y). If the address of an incoming entity matches the address in the register the coordinates are attached to the entity and its attributes and stored in the database. For certain institutions a hit rate of up to 97% percent is achieved with automatic geo-coding. The remaining few percents are evaluated manually, subsequently geo-coded or rejected as being invalid.

POI are classified as regards importance and availability and from this the revision frequency is decided. The system is under continuous development in order to automate the process. Through dialogs with information suppliers the system is being expanded and improved in order to minimise the manual interaction.

5.2 Place Names

Place names are treated differently. A city name, for instance, refers to a specific geographical area. The area is defined by a polygon encircling the city area and the name is attached to this surface. The updating procedure then comprises a check of the polygon whether it still holds the entire city area. The revised geometry database showing built-up areas is used in this process.

Some place names are authorised by the Danish Government. New place names are normally suggested by local authorities and must be accepted by a governmental committee. Members of the committee represent government departments and universities. An updated register holds the authorised place names.

The co-operation with The Statistics Denmark (statistical department) is important in order to ensure that city areas (statistical units) are defined unambiguously and that the various geo-spatial databases in the country operate with the same and updated version for use in GIS as well as statistical analysis.

5.3 SNSOR Update

Contrary to the TOP10DK geometry and the elevation model the register of names and POI is updated continuously. The update frequency for each type of POI depends on type of information, priority and availability. The priority is decided from the use of the specific POI or place name. For instance, a POI that is used in the travel planning application is classified as basis data and kept under continuous surveillance.

The register is strongly dependent on the external sources and agreements concluded between KMS and data providers.

6. DIGITAL ELEVATION MODEL

The third component of the TOP10DK concept is the digital elevation model (DEM). It is created from data of different origin and aimed to fit the general specifications of the database and to be used along with the various map products, separately or in GIS-analyses. At present it is produced in a 25-meter grid and as 2.5 meter and 5 meter contour lines.

6.1 Basic Data

Three types of data form the basis of the elevation model:

- 2.5 meter contours from old map sheets
- Certain object types from the geometry database
- Spot heights, i.e. points with local max. or min. elevation together with selected points that locally describe the shape of the terrain surface.

6.1.1 Contour lines: The history of the contour lines shown on Danish topographical maps goes back to the middle of the 19th

century. At that time maps were an army responsibility. It was decided that the surveying should be carried out by plane table measurements at scale 1:20.000 and with 5 Danish feet (1.57 meter) contour interval. From 1889 the contours were measured with an equidistance of 2.50 meters. In the middle of the 1960's photogrammetry was introduced to produce 1:10.000 map manuscripts. (Nielsen et al., 2002).

However, only a small part of the country was re-measured as regards the contours. The major part of the existing contours was interpolated by hand from 5 feet to 2.50 meter. The contours were digitised and labelled (index) automatically.

The first digital elevation model of Denmark was constructed solely from these contours in the late 1980ies (Frederiksen, 1987)

6.1.2 Database Objects: Certain objects from the geometry database are per definition linked to the terrain surface. Road centre lines and lakeshores are examples of such objects. The geometry database holds all three co-ordinates of these objects that are photogrammetrically measured during the revision procedure. So, it is obvious to include such objects as individual points to the basic data from which the elevation model is generated.

6.1.3 Spot Heights: A number of spot heights are identified at KMS and delivered to the photogrammetric companies together with all other material necessary for the revision. That is points with local maximum and minimum elevation and points that support the description of the terrain undulations. Typically, 400 – 500 points are identified pr. 100 km^2. The (x,y) co-ordinates are given to the producer who's task it is to measure the elevations photogrammetrically

6.2 DEM Construction and Revision

The elevation model is an in-house product calculated from the above-mentioned 3 types of data. It is believed that the contours describe the shape of the terrain surface quite well while tests have proved that the absolute accuracy varies from one part of the country to another. The photogrammetrically measured objects and the spot heights are included for two reasons: Firstly, to create coincidence between the TOP10DK objects and the elevation model and secondly to ensure the correct absolute level in the model.

Initially, two terrain models are created, one from the terrain points of the geometry objects and spot heights and another from the points describing the contours. The height difference between the two models is low-passed filtered revealing the significant differences between contours and geometry objects/spot heights. The contours are draped on the geometry data by subtracting the filtered data from the original contours preserving high frequency information and eliminating inexpedient trends from the contours. In this way the modelling takes advantage of the contours as a shape-describing component. Kriging is the predominant estimation method but also bilinear interpolation is applied (Ekholm, 1996).

The revision of the DEM is planned to follow the 5 years revision of the geometry objects. At the moment, the revision of the DEM is out of sync with the TOP10DK geometry revision cycle due to first priority on the production of 1:50.000 maps for the Danish Army. These maps include up-to-date calculated 5-meter contour lines.

When the geometry revision has passed the various check procedures and stored in the database, relevant objects for the DEM are extracted. Together with the contours and the newly measured spot heights the revised DEM is generated. This

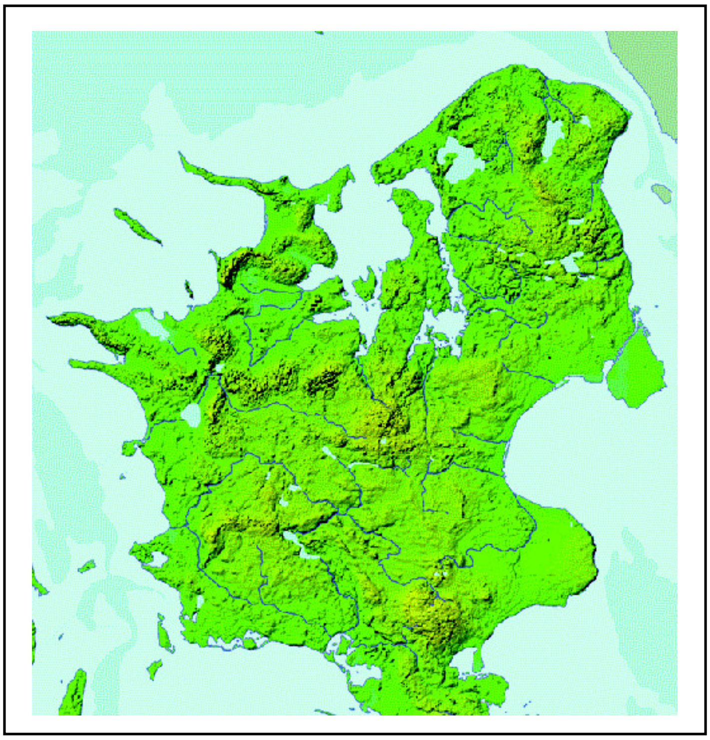

Figure 4. Digitale elevation model of Zealand, Denmark

means that the elevation model is the last component to be created within one revision cycle.

7. SUMMARY AND CONCLUSION

Different strategies are applied to the revision of the databases that make up the TOP10DK. The objects of the geometry part are revised in 5 years cycle – and for certain objects by an administrative procedure giving temporary object registrations being confirmed through the systematic 5 years revision. The elevation model is subsequently updated utilising the revised geometry and the photogrammetrically measured spot heights. The database containing information on place names and points of interest is continuously updated depending on importance and application of the information.

The performance of the TOP10DK databases is highly dependent on external data providers, either as subcontractors or as partners. There is always close contact between the photogrammetric companies and KMS during the revision process. An optimal revision is based on confidence and co-operation. It has proven a successful strategy that minimises the efforts for final in-house control.

Extended co-operation with external data providers concerning administrative revision for both temporary geometry and information on place names and point of interest is promising and is obviously leading to better performance of the geo-spatial databases.

REFERENCES

Ekholm, S., 1996. A full coverage, high-resolution, topographic model of Greenland, computed from a variety of digital elevation data. *J. Geophys. Res.*, pp. 21.961 – 21.972.

European Environmental Agency, 2004. INSPIRE Scoping Paper.

Frederiksen, P., 1987. A Digital Elevation Model for Radio Communication. In: ISPRS Proceedings of The International Colloquium, Progress in Terrain Modelling, Copenhagen, Denmark, pp. 127 –133.

Hoejholt, P. and J. Grum, 1999. Revision of Maps Registrating only True Changes. In: *Proceedings of 19th International Cartographic Conference*, Ottawa, Canada.

Hoejholt, P., 2004. Personal Communication.

Kamper, J. 2004. Control Procedures for Topographic Map Databases Set-up and Update. In: *Proceedings of ISPRS XXth Congress*. Istanbul, Turkey.

Nielsen, S. R., Christensen, S. F. and Michaelsen, P. B., 2002. Topographic Mapping in Denmark. In: *The Danish Way.* Publication no. 10, The Danish Association of Chartered Surveyors. Copenhagen, Denmark.