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Large-scale strategic noise mapping - using tiled acoustic models

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ABSTRACT

Strategic noise mapping of large areas challenges the performance of noise computation software, not only with respect to calculation times, but also in the process of generating the comprehensive acoustic model. These models encompass a huge amount of data.

In order to manage these large datasets, the model has to be divided into manageable parts or tiles. A tiling even facilitates the recalculations of large-scale, dynamic noise mapping, e.g. when doing environmental impact assessments or action planning.

Large-scale noise mapping using tiled models requires optimised methods for data processing and a well organised structure for data filing and management.

This paper describes the methods and tools developed for noise mapping of the major road network in Denmark and END mapping in England, including:

- automated methods for attributing and tiling of the geometric data within GIS
- quality assurance of data and calculation results
- management and generation of tiled models and batch calculations in the noise computation software
- export, processing and aggregating of calculated results of each tile into a total noise map
- assessment and presentation of results

1. INTRODUCTION

Large-scale noise mapping requires collection and processing of a substantial amount of digital geometric data. Even with modern noise computation software and the latest computer hardware, there are limitations to the amount of data that can be handled with ease in the process of generating an acoustic model.

To facilitate generation and management of large acoustic models, it is advantageous to divide the model into smaller parts or tiles, i.e. a number of equal sized squares.

Today, various methods for division of acoustical models into more manageable parts are available with modern noise computation software packages. The basic structure and methods of the noise mapping project described were chosen before this opportunity was readily accessible.

The objective was to ensure noise mapping based on flexible and dynamic acoustic models that subsequently can be updated and refined with more detailed geometry.

Using tiled acoustic models has obvious advantages:

- easier handling of small model parts
- easy update and refining of model parts
- easy re-calculation of model parts
- easier error location and correction on small model parts

However, several drawbacks exist as well:

- import of a large number of files into the noise computation software is required
- increased workload with management of input data and results
- need for automated methods for the model generation and the setup of batch calculations

2. DIVIDING THE ACOUSTIC MODEL

A. Division of the model into manageable parts

As a starting point, it was decided to split the acoustic model into five separate sub-models each covering one of the administrative regions in Denmark.

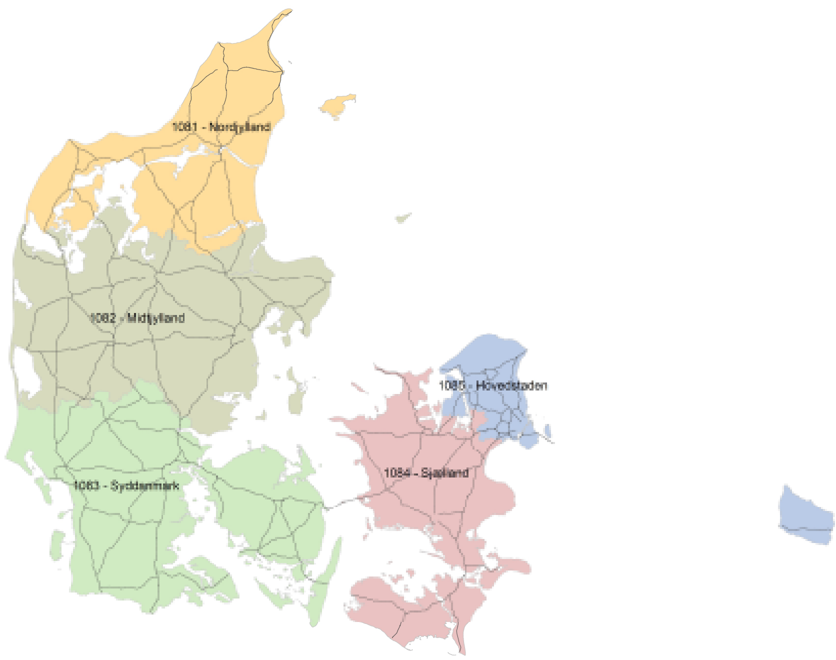

Figure 1: The five administrative regions in Denmark

Even with this division, the resulting sub-models would encompass too large an amount of data to ensure an easy handling and noise calculation, and it was necessary to divide each sub-model into even smaller parts.

It was decided to establish a method for tiling an acoustic model into a number of equal sized squares (tiles).

As a basis for this, a national Danish system with a grid of squares used to divide and reference geometric datasets covering the entire country was chosen. The system can be used with a various number of same-size squares ranging from 100 m to 10 km, each identified by the geographic coordinate of its lower left corner.

B. Determination of the optimum tile size

When tiling a large acoustic model, the determination of the tile size has to be based on careful considerations. A large tile size results in fewer tiles and consequently less extent of data management, but it increases the model's total amount of data as the amount of more remote, non-essential data is increased.

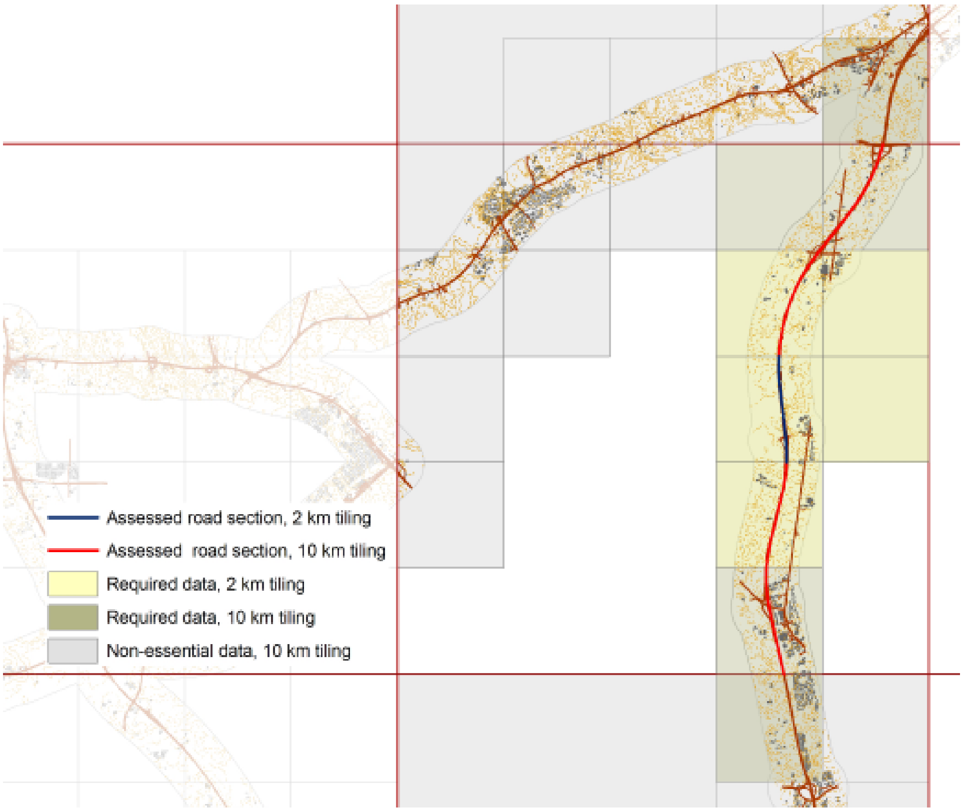

Figure 2: Using a large tile size (10 km) vs. a smaller tile size (2 km)

Another criterion to consider when determining the optimum tile size is the search radius set within the noise computation software, i.e. the extent of a single tile should be larger than the largest search radius used.

Based on the above considerations and a search radius set at 1000 m, a tile size of 2 km was chosen and a grid of squares covering the road network was generated, containing a total of 3,288 tiles.

3. METHODOLOGY

A. Software

The noise mapping was carried out using commercial software products and utilities necessary to support data processing and management were developed using Visual Basic for Applications (VBA).

Noise computation was done with SoundPLAN ver. 6.4 and the implementation of the new Nordic prediction model, NORD2000.

Pre-processing - i.e. collection - analysis, attributing and tiling of datasets were done with ESRI ArcGIS Desktop ver. 9.x.

Management of the tiling of the datasets, layout for generation of the tiled models and setup of the batch calculation structure in SoundPLAN was done using a Microsoft Access database.

The calculated Grid Noise Maps, exported from SoundPLAN, were aggregated using stored procedures within Microsoft MSSQL server and the graphical noise maps were generated and plotted using ESRI ArcGIS Desktop.

The result of Façade Noise Map calculations done with SoundPLAN are stored in Paradox database tables. The resulting tables were aggregated, analysed and reported using Microsoft Access databases.

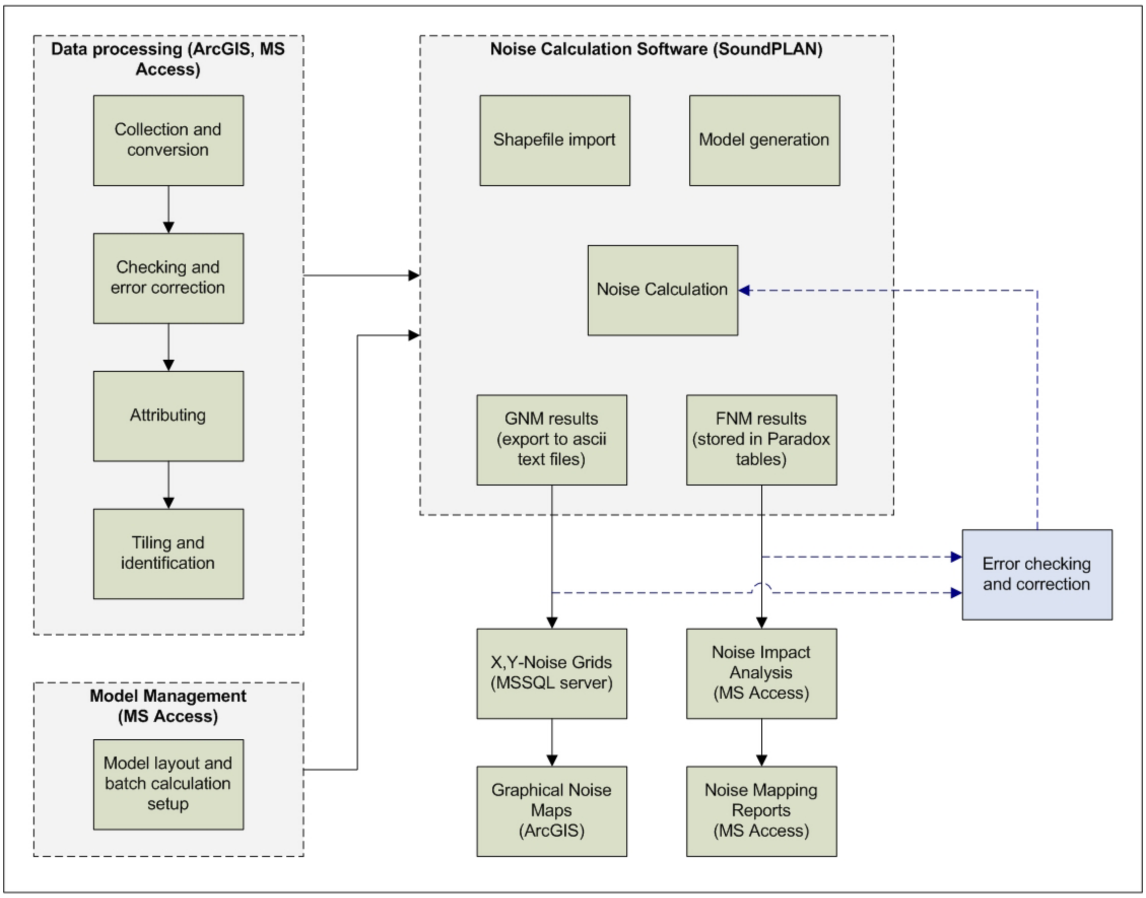

Figure 3: Data processing and noise mapping flow diagram

B. File formats and folder structure for file storage

Management and storage of many geometric objects in large datasets requires an unambiguous naming convention and a systematic filing structure in order to prevent errors.

For each of the five regions, all collected geometric datasets were converted to the ESRI shape file format. Each geometric object type was saved in separate shapefiles and named with an abbreviation to identify the contents, e.g. BU for datasets containing buildings, RO for datasets containing roads etc.

All datasets change during the execution of a noise mapping and a folder structure was set up to store the datasets for the different stages of the data processing, noise calculation, analysis and reporting of the results.

Table 1: Folder structure for storage of datasets in various stages of the data processing

Processing Stage	**Folder**
Collected datasets	\BASIS\<region>
Pre-processed datasets	\DATA\<region>
Tiled datasets	\PREP\<region>\<object type>
SoundPLAN models	\SPMODEL\<region>
Calculated Grid Noise Maps	\RESULT\<region>\GNM
Calculated Façade Noise Maps	\RESULT\<region>\FNM
Exported Grid Noise Maps	\RESULT\<region>\TXT
Final results and reports	\FINAL\<region>

C. Identification of geographic objects

Every single object was assigned two identification codes. A primary code is assigned to all continuously geometric objects during pre-processing, e.g. a serial number to identify each building.

The secondary code is assigned in the process of tiling the datasets. This code consists of a reference to the tile in which the object is located (the geographic coordinate of the lower left corner) and a serial number - YYYY_XXX_N.

Using two identification codes makes it possible to relate and join tiled geometric objects to non-tiled attribute data, e.g. joining traffic flow to a road centre line, using the primary identification code.

The secondary identification code enables easy geographic tracking of objects, e.g. in connection with error correction.

4. TILING THE GEOMETRIC DATASETS

The tiling was done on all geometric datasets for each of the five sub-models as the end stage of the data pre-processing.

The utilities for tiling of the datasets were developed in VBA, using the necessary functions provided by the ArcGIS component object model.

The grid of squares covering the road network was loaded together with the dataset to be tiled. While stepping through all of the squares, the present geometric objects were clipped by the outline of each square and saved in a separate shapefile. Not all squares comprise all geometric object types, e.g. noise barriers are not present in all squares, and therefore no clipping was done and no shapefile saved to the specific folder.

Building polygons could not be clipped by this method, as it in some cases would cut a building into several parts. Building polygons were "soft clipped" by means of their label point (a point always inside the polygon) generated as a geometric object for each building. While stepping through all of the squares, the points contained by a given square were selected and by selecting the building polygons, which contain the previously selected points, the buildings could be saved to a new shapefile.

During the process of tiling, each geometric object was assigned the secondary identification code, i.e. the reference to the actual square, read from the given record in the attribute table of the squares, and a serial number representing the sequential count of the current object.

Each shapefile was named with an abbreviation for the actual object type, followed by the reference to the square used for the tile, four digits used for optional coding and terminated by the size of the tile. As an example a shapefile named "RO_6174_704_01_00_02_02.SHP" would be a tile containing:

RO (road network); 6174 (Y-coordinate of 6174000); 704 (X-coordinate of 704000); 01_00 (major roads); 02_02 (a tile size of 2 by 2 km).

The shapefiles for the tiles of a given dataset were stored in a separate folder according to the convention previously described, ready for import into the noise computation software.

5. GENERATION OF THE ACOUSTICAL MODEL

A. Management of input data and generation of model layout

An acoustic model generated with SoundPLAN can hold several "situations", each containing a selected extent of geometry saved within the SoundPLAN model as "geofiles".

All the applicable shapefiles were imported into the SoundPLAN model as geofiles and named as its parent shapefile according to the convention described above. For each of the tiles covered by the model, a situation containing the geofiles with the geometric objects of relevance for the tile in question plus the geofiles for up to eight neighbouring tiles was set up. This technique ensures that the calculated noise level everywhere in a tile comprises of the noise contribution from all relevant sources.

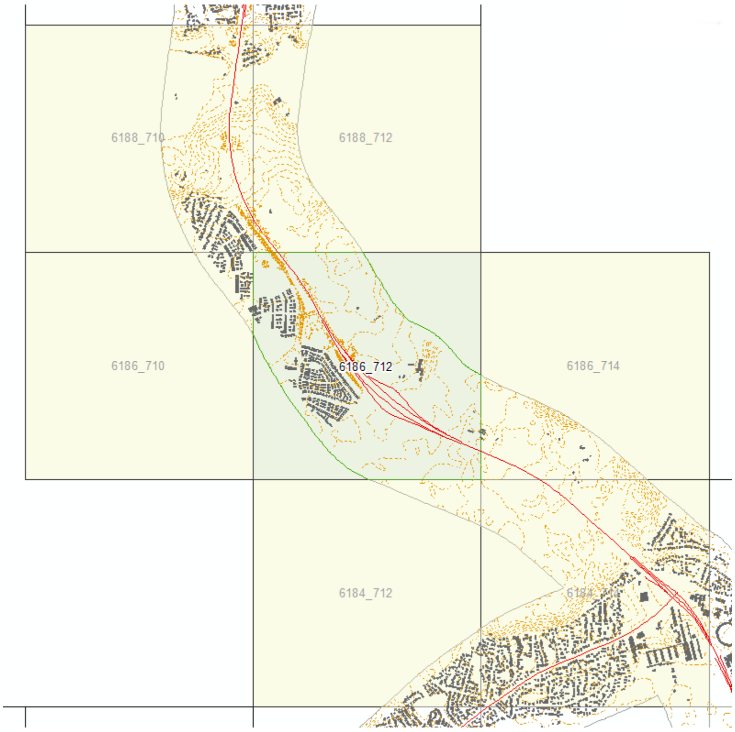

Figure 4: A situation containing the geofiles of a selected tile and the six neighbouring tiles

The layout for each situation was generated using an MS Access database with several utilities developed in VBA.

As a starting point, a utility was used to find the relevant neighbouring squares of a given tile and write this to a table within the database.

Another utility was then used to step through all the tiles and search for the presence of shapefiles with a reference matching the current tile and the relevant neighbouring tiles listed in this table. For each tile, being a situation in SoundPLAN, the belonging geofiles were identified by the matching shapefiles of any of the included geometric object types found. The names of the situation and of the belonging geofiles were written to an ascii text file.

This utility was used to layout the situations for the noise calculation as well as the situations containing only terrain elevation for calculation of the belonging Digital Ground Model (DGM).

To ensure that all shapefiles were imported to SoundPLAN and correctly named, another utility was used to check for the presence of all the geofiles in the SoundPLAN model corresponding to the tiled shapefiles located in the folders for tiled datasets.

B. Generation of the acoustic model and setup of batch calculation parameters

A situation in SoundPLAN is described by a simple list with the name of the situation and the name of each geofile contained within the situation. To translate the ascii text files into situations within SoundPLAN, the software supplier developed a specific tool for COWI to perform this task. With all the required geofiles present in the SoundPLAN model, running this tool will set up the planned situations based on an ascii text file.

Within the calculation module of SoundPLAN, batch calculations were used to calculate the DGM, the Grid Noise Map (GNM) with a receiver height of 1.5 m as well as 4.0 m, and the Façade Noise Maps (FNM) for each tile. The calculation results can according to a restricted SoundPLAN structure, only be named using four digits. To comply with this limitation, each tile was assigned a specific serial number for the calculation of the DGM (9xxx) and the calculation of the GNM with a receiver height of respectively 1.5 m (1xxx) and 4.0 m (4xxx) and the FNM calculation (7xxx).

The batch calculations and the attached calculation parameters are stored in the SoundPLAN model as a Paradox database table with the file extension renamed to "run".

The setup of the batch calculations, i.e. naming of the batch job and the result, specification of the situation and the belonging DGM and setting the calculation parameters were done using an MS Excel spreadsheet, which facilitates the use of formulas to build the parameter strings and the use of copy/paste to propagate data to multiple records. The spreadsheet was linked to an MS Access database and the records appended to an empty "run" file using an action query. This was done to generate separate "run" files for the calculation of the DGM, the calculation of the GNM at the two different receiver heights, and the FNM calculation.

When running the batch calculations within the calculation module of SoundPLAN, a log file (*.res) is generated for each tile, holding information on calculation data, spent calculation time and potential errors. With the model manager database, a utility was written to step through all the log files, select relevant information for each tile and insert the data into a table in the database, which then could be queried to select tiles with errors. As the calculations were performed on a copy of the acoustic model, the errors could be located and corrected within the original model without halting the batch calculations. After finishing the batch calculations, the corrected tiles were recalculated.

6. ANALYSIS AND PRESENTATION OF THE RESULTS

A. Grid Noise Maps

By a routine in the Graphic module of SoundPLAN, the GNMs calculated for each tile (RRLK1xxx.gm/RRLK4xxx.gm) were exported to ascii text files containing the X,Y-coordinate and the calculated noise levels, L_{DEN}, L_{Day}, $L_{Evening}$ and L_{night} for each grid point. The structure of all the text files was changed with a text editor (UltraEdit-32) to comply with a standard, character delimited ascii text format.

To store all the GNM results, a MSSQL server database was set up. In the database, a stored procedure was developed to import and aggregate all the text files into a single database table for each of the five regions.

Noise maps were made within ArcGIS by a sequence of operations to generate a raster grid, which can be presented with its raster pixels representing the grid size or interpolated into noise contours. To automate this, the Model Builder was used to set up a tool, by which only the MSSQL database table, the grid size, the fieldname for the required noise indicator and the name of the resulting raster grid needed to be specified.

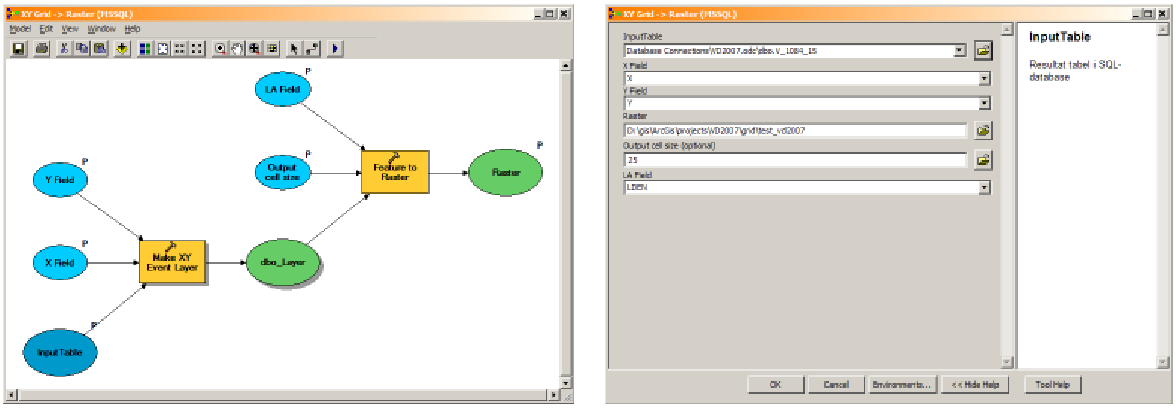

Figure 5: The ArcGIS Model Builder was used to generate raster grids

The noise maps were plotted with the raster grid, set to a chosen level of transparency and overlaying a topographic map or an aerial photo.

B. Façade Noise Maps

A FNM calculates the noise level at a specified number of points at each façade and on every floor of a given building.

The results of the calculated FNM are stored in a Paradox database table (RREC7xxx.db) for each tile within the SoundPLAN model. The tables from each of the five SoundPLAN models were all linked to a separate MS Access database. By a routine written in VBA, the content of the tables was aggregated into a single table in the database.

In order to assess the noise impact, the maximum noise level at each floor was queried for each building and linked to a register holding information about each building, e.g. utilisation of the building and the number of dwellings. By a set of queries in the database, the total number of affected dwellings was estimated. The results were reported per 5 dB noise interval, grouped by built-up areas and utilisation of the buildings.

7. CONCLUSIONS

The methods and utilities described in this paper have been used for several noise mappings carried out for road and railway networks.

The use of tiled acoustic models is advantageous to large-scale noise mapping projects that require subsequent refinement of the geometric datasets or successive re-calculation for several scenarios. The work required regarding planning, management and processing of geometric data is far too extensive for smaller projects.

A major draw-back when performing a large-scale tiled noise mapping is the somehow tedious task of importing a very large number of shapefiles, as SoundPLAN does not support import of multiple files.

The near unlimited processing capabilities provided by today's advanced GIS software combined with the possibility of advanced presentation of maps and linkage to external attribute data will in many situations be more advantageous than even the most advanced tools within commercial noise computation software.

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