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GIS AND NOISE MAPPING – RECENT SOLUTIONS

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Abstract

The European Noise Directive 2002/49/EC focuses on noise mapping calculation for large areas. This requirement generates various challenges for noise mapping authorities including: data collection, data post-processing, large volume data management, control of results uncertainty, calculation processing time, result presentation, interaction with public and data maintenance. This paper will address different degrees of integration of GIS and Noise Mapping Software and will provide an overview of approaches successfully employed to address the technical challenges during a number of recent projects, including Manchester and Merseyside for the Noise Mapping England (NME) project, and the set up of a noise mapping and case study model for the area of Freistaat Sachsen (~20,000 km²).

INTRODUCTION

The European Noise Directive 2002/49/EC (END) has created a requirement for noise mapping over large areas. When such a calculation process begins with highly detailed datasets, such as the central service (CDS) of the recent “Noise Mapping England” (NME) project, this presents a series of challenges for the project team, and the software tools used during the mapping process.

Collecting and maintaining such datasets may have previously been tasked to the acousticians utilising functionality available within some of the advanced noise mapping software available [1]. Increasingly, however, management and manipulation of the large datasets will be within the domain of modern geographical information systems (GIS) systems which may provide a centralised geospatial data repository for multiple projects and technical disciplines within a spatial data infrastructure (SDI) [2].

During the current first stage of the END related noise mapping excursive, only major agglomerates and inter-agglomeration transport routes need to be addressed, however the second phase will also deal with smaller agglomerations, and lower trafficked routes. When combined, the requirements can create a need to model significant proportions of a region, federal states or even a whole country, and it may be deemed desirable to complete the process by modelling the entire region. The purpose of such maps may be the political desire to simulate complete regional scenarios, or provide links to other modelling exercises within other domains, such as air-quality or land use management. Such an approach was taken for the German federal state of “Freistaat Sachsen”.

The demands placed upon existing sources of data required for noise mapping to this extent often leads to variable levels of quality and resolution available across the different input datasets, and across different portions of the project area. Recent work published by Defra [3] in support for WG-AEN “Good Practice Guide” (GPG) v2 [4] can help GIS and acoustics professionals work together to make informed decisions about the importance and impact of dataset imperfections to help manage the uncertainty within the mapping results. The GPG v2 also helps by setting out a series of options to help fill in areas where data may be unavailable, or propose situations where data capture may be the preferred solution.

This paper will summarize some of the experience made in the projects mentioned.

DATA MANAGEMENT STRATEGIES

In the early days of noise mapping the acoustics team lead the projects, and the acoustics software was a completely separate stand-alone product which held the prominent position within the project. The users had to learn how to handle a specific geometry and data manipulation tool, and had to set up models from scratch. This has lead to the noise mapping software systems having a wide range of bespoke, incompatible, object and attribute data formats.

More recently, exchanging of datasets via common file formats, such as GIS and CAD standards, has become possible. This approach is currently being formalised with the German draft DIN 45687 [5] proposing the ESRI shapefile format as the approach to data exchangeability between different noise mapping software packages.

File based data exchange serves an important role within the noise mapping process, however it also open up the risk of maintaining independent sets of model data within GIS, CAD and the noise software, which significantly stretches the change management process, and risks inconsistencies between models.

Integrating acoustic software in GIS

Increasingly, the means by which GIS and noise mapping software systems are integrated becomes an area of discussion when seeking to reduce the workload and risk, whilst simultaneously increasing consistency and traceability. Discussion of the form of integration which may be utilised naturally brings up the issues associated with how the GIS and analysis systems may be linked together. The means by which models and GIS are connected together is not trivial, and many approaches have been used. There are broadly three generalised means of linking GIS with external models, as identified by Mandl [6]:

- **Loose Coupling:** where the two exchange data and results through files;
- **Tight Coupling**: where not only data but other information is shared between the two tools; and
- **Full Integration**: where the modelling and spatial operations are integrated into one software product.

Within a tightly coupled or fully integrated system, the development and management of the model datasets are carried out by GIS operators within their familiar GIS environment. The acoustic calculation software is then used to process the noise level calculations in the background, or even on computers distributed in a net. The movement of data into and out of the noise calculation kernel is handled automatically within the GIS environment, thus providing potential improvements in timescale, quality management and traceability.

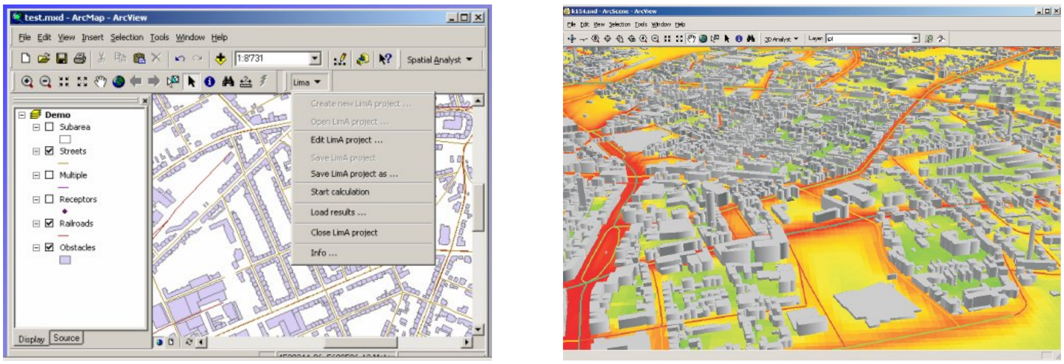

Figure 1 - Screenshots from ArcGIS with LimAarc plug in

An example of such an application is LimAarc [7]. As a plug in to ArcGIS, it assembles the model data for calculation from the central GeoDataBase. Object types, their attributes and related help information are automatically available as they are customized in the LimA software.

Integrating acoustic software in Intranet or Internet

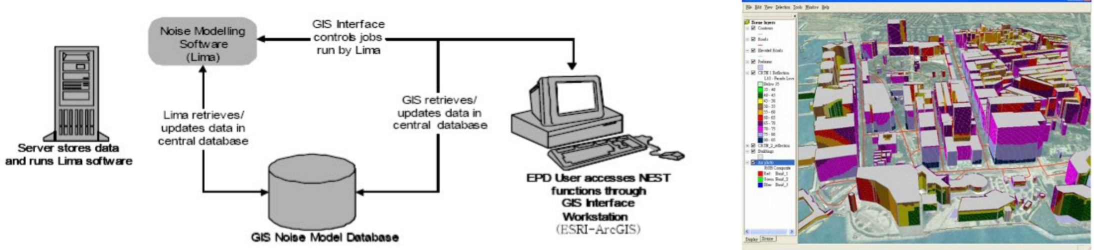

Figure 2 - Concept of Hong Kong Intranet application

An extension of this approach has been followed in Hong Kong [8]. Here the Environmental Protection Department decided to set up a server for noise calculation in their intranet environment, which has access to Hong Kong model data. LimA acoustic calculation software is installed on a separate server.

Through a special Web interface [9], designed by a local Hong Kong company, any public authority linked to the intranet can retrieve noise level results or start calculations on their own demand. This reduces the needs for additional software licenses and ensures quality of the model data used.

GIS DATA PROCESSING

GIS data is collected for multiple purposes and this will generally not be specifically for the needs of acoustic calculation, hence it is seldom optimised for such a use. This leads to two generalised groups of issues which need to be resolved for the data to be optimised for the noise calculations:

- Tuning dataset resolution to acoustic calculation requirements; and
- Appending datasets to best exploit capabilities of the calculation kernel.

Dataset resolution

Many modern general GIS datasets are designed for urban property management and have high resolution datasets to enable detailed work to be carried out. The level of resolution within these datasets may often be suitable for use within calculations of noise when planning cases or specific investigations are envisaged. However the level of detail provided may be considered overly high when the end results are for wide area noise mapping purposes. It is also important to consider that the noise calculation methods being used are generally more sensitive to uncertainty in the vertical, z, axis, than the horizontal, x and y, axes.

As an example you may think of highly detailed façade geometry, which may need to be generalised in order to avoid the “size of reflector” criteria skipping a reflector. Or ground terrain contour datasets with points defined every 10cm, when horizontal deviations away from this “benchmark” dataset of up to 25cm would produce almost no change in calculated noise result, but a “smoothed” line reduce data volumes by up to 85%, and thus significantly reduce the required calculation time.

There are two recommended approaches to dealing with managing dataset resolution issues:

- Any necessary geometry processing is automatically done in the calculation software. Here the acoustic software is designed to interpret real world geometry in a sophisticated manner; and
- Geometry processing is carried out within a process which manages the uncertainty introduced. Here any changes carried out to the input datasets are tested by running samples through the noise calculation kernel, and

assessing how the changes in datasets produce changes in noise results.

The later approach was taken during the recent NME projects for Manchester (1,400 km^2) and Merseyside (750 km^2). Here the highly detailed ground contours, areas of soft ground, road centrelines and building polygons were all generalised in order to reduce the volumes of data which the noise calculation software needed to process. The key to this process of generalisation was the use of benchmarking, and testing of the options for simplification to ensure that all the simplifications, across all the data-sets, when combined introduced less than 1dB(A) of uncertainty, when compared to the original benchmark datasets, whilst providing a 45% reduction in calculation time.

Optimising Datasets

Converting 2-d data into 3-d

Acoustic models need to work in 3-d. If z information per vertex of the geometry is not available, extra attribute information will be assigned to 2-d geometry to create the 3-d model. For convenience in setting up data we suggest the support of:

- absolute heights
- relative heights to terrain
- relative heights to buildings (e.g. screen on bridge)
- relative heights or gradients in slope constructions (e.g. 2-d embankment next to railway axis in 3-d coordinates)

Whereas roads are generally set to a height of 0.0 relative to the ground, this will be of no help for flyovers. Unfortunately bridges are often not part of the building or ground datasets. In Hong Kong extra road attributes were used to describe flyovers, parapets, semi enclosures and enclosures, as they were known to the road planning department. The LimA concept of user defined objects and attributes allows an easy customisation of the software for such cases. Therefore the extra attributes can be used to automatically generate the related geometry after the calculation core reads the model data.

Recently the Environmental Noise team of Birmingham City Council organised car trips along their circular highways, which are elevated to a significant extent. Whilst driving, 3-d GPS data was collected on a laptop, which was then processed in IS to create a set of 3-d line segments. In the acoustic software GUI, these were then automatically concatenated into polylines, and converted into 3-d bridge constructions.

Automatic reshaping of terrain

As mentioned before, road net geometry will mostly be available in 2-d and as a first approach the road is fitted onto the top of the digital terrain model. The problem arises where terrain models are based on 50 m grid positions, for example, or where terrain models try to differentiate between natural terrain surface and artificial embankments. This can result in obscure road gradients and may underestimate barrier effects caused by natural terrain next to the road.

This was the situation encountered in the Sachsen project, where very detailed data was available in some areas, such as Dresden, and only very general data existed in the rural parts. For the relevant roads, i.e. federal roads and highways, the road planning directives limit the longitudinal gradient, and the vertical curvature, according to road classification and speed restrictions. In the post-processing of the imported data this information was used to estimate positions where roads are well above terrain or submerged. Here the terrain was automatically reshaped assuming a maximum gradient of the adjacent slopes. Considering that the total model area covers 20.000 km², this task could only be performed automatically and LimA was enhanced to support this feature.

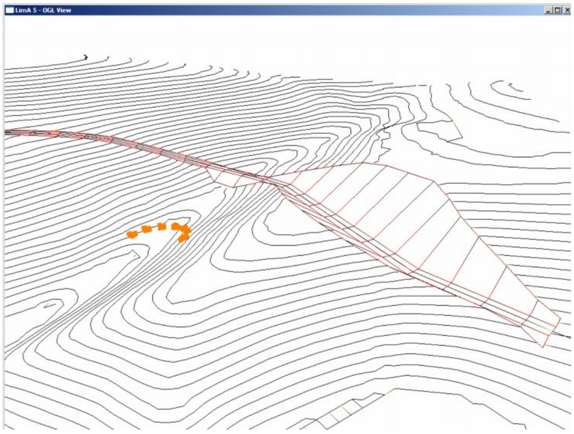

Figure 3 - Automatically reshaped terrain

Inheriting object attribute information

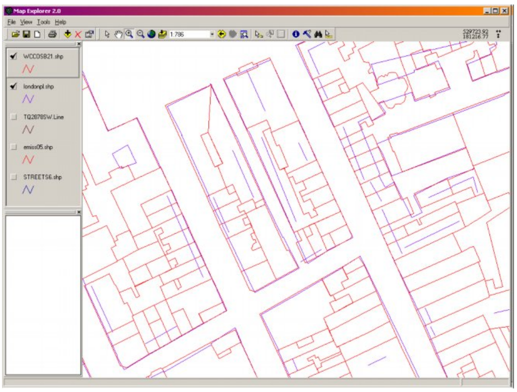

Figure 4 - Matching building data

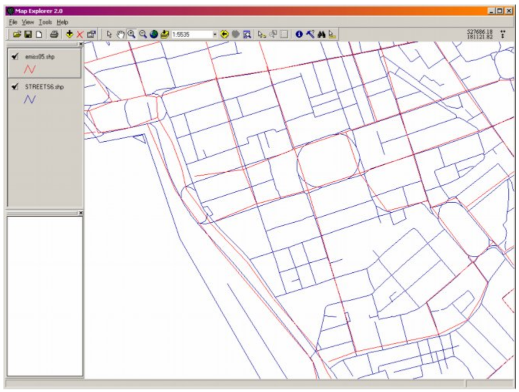

Figure 5 - Matching road data

Where accurate object geometry is only available in 2-d or is missing essential attribute information, which is available in other sets of data of less accurate shape, automatic strategies can be of great help. For example LimA's MATCH command will allow searching for related geometries in the two sets of input data and will pass on attribute information for matching objects. The examples shown below were taken from the Westminster City Noise Map.

Using Laser scan data (LIDAR)

As part of the Sachsen project, a highly detailed set of model data had been created for the agglomeration of the City of Dresden. 2-d geometry of all buildings existed in the City cadastral data (> 1.000.000 façade segments) and 7 GB of LIDAR data was processed to gain heights of the eaves of buildings. Also terrain contour lines were developed from the scan data. Here it was important to filter miscellaneous reflections from cars, lampposts etc. Furthermore the Dresden model consisted of approximately 55.000 road segments.

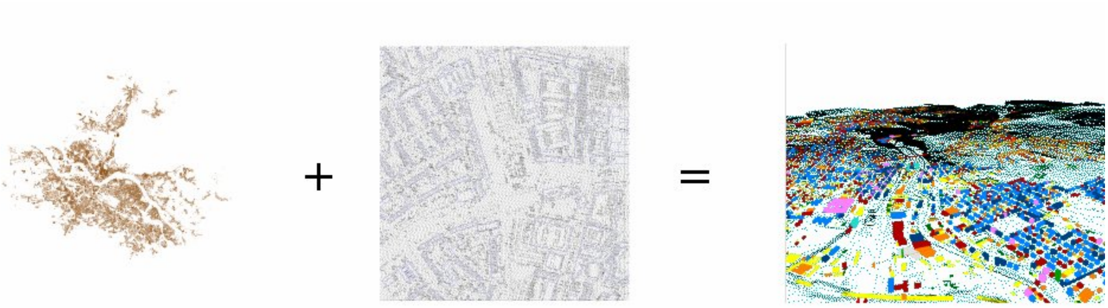

Figure 6 - Creating 3-d city model from cadastral and laser scan data from 2-d building shapes and x,y,z topology data from laser scan

CALCULATION

Fast calculation requires that all relevant model data is kept in memory during the calculation. This leads to the development of tiled calculations, with the extra advantage of different tiles being processed in parallel on different processors. With GB's of memory available today, a single tile may consist of 10 million obstacle edges in LimA's largest configurations. In practice this will rarely be necessary.

Key figures of calculation for Dresden:

360 km²	Calculation area
2.500 m	Fetching radius for emitters
30 m	Fetching radius for reflectors
10 m	Width of calculation grid
3 dB	Dynamic error margin
0.24 dB	Average deviation in QA analysis with standard deviation $\sigma = 0.19$ dB
< 4 days	Calculation time on 4 processors

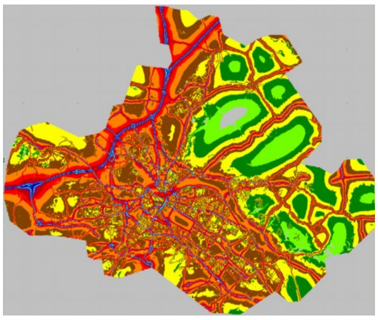

Figure 7 - Dresden day time noise levels

For each calculation a number of parameters have to be defined by the users. This will influence accuracy and calculation time. Some of these parameters are easy to understand and will result in similar effects for all acoustic software packages, such as the fetching radius for emitters. However more sophisticated techniques, such as the dynamic error margin, may work differently in different software systems.

Dynamic error margin

In LimA the dynamic error margin describes the maximum tolerated increase of noise level results that will occur if all sources that are neglected for a certain receptor position happen to be in an unscreened position. When deciding to use such parameters, the user needs to justify his settings by comparison with crisp calculation settings for random test calculations, e.g. for 1 out of 1000 grid positions. The acoustic software offers tools to create error statistics.

Threshold minimum noise levels

Another strategy to reduce calculation time may come into effect while performing calculations for the END, as the directive is only interested in noise levels above certain values. When the users define these threshold values, LimA will recognise areas that are definitely of no interest and will avoid calculating grid positions in this area. This analysis is done conservatively as screening and reflection effects cannot be predicted without actual calculation.

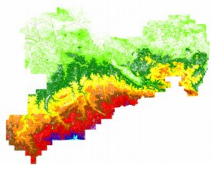
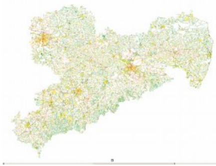
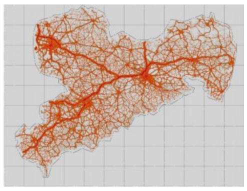

Figure 8 - Model data and results for 20.000 km² of Freistaat Sachsen
> 5.450.000 contour lines > 314.000 roads (~600.000 seg) Lden results > 55 dB

Combining calculation settings

It is important to realize that the time savings provided by the user selectable calculation settings within noise mapping packages are not provided without some compromise in the results obtained. As with the data economization processing, the NME projects for Manchester and Merseyside followed a structure process whereby the uncertainty introduced by the various calculation parameters was tested and compared to the benchmark results. By this means, the total calculation time was reduced by 87%, whilst only introducing 0.35dB(A) 95% CI uncertainty into the results. This demonstrates that result quality does not have to be discarded in order to produce fast calculations.

CONCLUSIONS

GIS is increasingly being seen as the most appropriate tool to organize large sets of model data as required for the purpose of noise mapping for the END. Not every GIS will provide all the data manipulation tools required to maximise the potential of the datasets for noise mapping purposes. When the necessary data post-processing can be performed on the fly within the acoustic calculation software, or the calculation kernel embedded within a tightly coupled system, this will help to avoid keeping parallel sets of data and therefore help to improve quality and traceability within the mapping process..

The Calculation of the 20.000 km² Noise Map of Freistaat Sachsen showed that it does not require excessive numbers of hardware and software licenses to create accurate noise maps for large areas, whilst the NME projects for Manchester and Merseyside demonstrate that significant time savings can be created by simplification in model datasets, and selection of calculation settings, without abandoning accuracy.

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