Optimising uncertainty and calculation time

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Since software based noise mapping started, the computational power has increased dramatically. Parallel to this, the demands on the software rose, in terms of model size and calculation accuracy. This is why efficiency techniques are still required to produce noise maps within reasonable time. There may be many ways to produce "coloured maps", but they will be of little value, unless there is a clear understanding of the implications that chosen efficiency techniques will have on the accuracy of results. The strategies will focus on different aspects of the noise mapping process and some techniques will produce an arbitrary error while other will result in a clear bias. This paper will address various techniques and give an overview of how efficiency techniques affect calculation speed and result uncertainty.

Aspects are:

- Source representation, e.g. area sources by point or line sources, line sources as points
- Line source segmentation, e.g. constant angle, constant length, method of projection
- Model simplification prior to calculation
- Model simplification on the fly, i.e. in relation to source and receiver
- Suppression of sources identified as irrelevant at the receiver

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1 Introduction

The political wish to set up noise maps for agglomerations with an accuracy that enables coming to conclusions on development plans of significant financial impact, created the need for software tools that economically can calculate huge acoustic models. Strategies for speeding up calculation are required, such as [ref 1]:

- Recognition of the relevant parts of the total model for each receptor position
- Simplifying geometry prior to calculation or on the fly
- Considering other than rectangular grids at constant intervals

Most of the software tools will support all three approaches and the user might influence each strategy by setting individual calculation acceleration parameters. Deciding on which parameter values to use needs acoustic noise calculation experience or consultancy advice, such as given in the Good Practice Guide [ref 2]. Still it will need to be proven for the individual project.

2 Statistic Verification

The choice of calculation acceleration parameters can be rectified by comparing results against those achieved with more conservative parameters. Measurements are less useful for this, but will be needed to unveil wrong model assumptions. As the effect of the 3 described strategies will vary for each receptor position, a number of test positions have to be used and the differences in results are processed statistically. Statistical indicators can either be mean difference and standard deviation or retrieved quantile values. The 10% and 90% quantile is suggested in the draft version of DIN 45687 [ref 3] to describe the reliability range of results. Here it is suggested to order the differences according to magnitude and extract the two values at position N(q0.1) and N(q0.9),

with N(q0.1) = Integer ((N+4)/10)

and N(q0.9) = Integer((N x 9)/10)+1

and N > 50 being the total number of samples.

As an aim of the noise mapping, we want to ensure that the calculated value for a receptor grid position is representative for the whole cell (area) around a receptor point. If not, one needs to consider decreasing the grid increment. To check validity of the chosen grid increment, the differing receptor positions inside the grid cell can be selected and the effect on receptor level statistically processed as describe above.

This paper will use the described approach to document the overall influence of user selectable parameters in geometry handling and calculation.

It is a different subject, that known or estimated uncertainties, which may be defined as object attributes for emission data, obstacle heights, reflection loss or as general uncertainty on the propagation path, can be processed during calculation to provide an overall uncertainty at each receptor position.

3 Recognition of the relevant data

To regard the influence of all sources for each receptor within a model that might cover 10000km² or more, is technically almost impossible, economically not feasible and with respect to the underlying propagation model just inadequate. However it is an open question, up to what distance sources should be fetched. And when a value is chosen, the way how a software handles the source fetching radius may vary. Both aspects contribute to uncertainty of results.

3.1 Fetching sources

During calculation some sources or barriers may well be neglected without any significant influence on the results.

A simple example is seen in the limitation of the search distance for relevant sources. It is assumed that an increasing the maximum radius will lead to an asymptotic rise of noise levels. In German DIN 45682 [ref 4] the maximum search radius is given from different types of sources, e.g.:

Highways	3000 m
Inner city trunk roads	1200 m
Inner city local roads	400 m
For industry, different values ranging between	
Lw > 125 dB	3000 m
Lw > 95 dB	300 m

For the industry case it can easily be envisaged that the way the acoustic model is set up might significantly influence results. For example, whether an industrial plant or site is modelled as a collection of individual sources or as one or more combined sources will determine the fetching radius. The fetching radius suggested for roads, may be investigated as well. It is based on the noise level distance relation for a long straight road.

For a typical highway usage with Lme=73dB at 25m and a receptor at a height of 4 m the distance and ground influence result in a receptor level of about 30dB. This is the lower edge of the lowest noise level category the DIN is focussing on. In practice, ring road highways are common (see Fig 1) and the criteria above may be misleading.

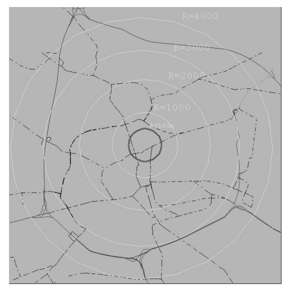

Fig. 01: Highway ring

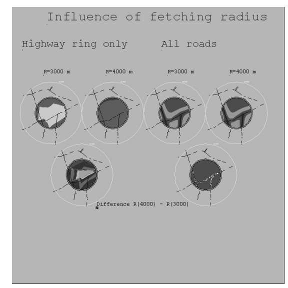

Fig.02:Centre situation

The example above is has a ring road of mainly highways with emission levels between 68 and 77 (dB), defined as Lme in 25m (RLS 90).

Increasing the fetching radius from 3000m to 4000m results in differences of almost 10dB (fig. 02, on the left), when only the highway is considered. Once local roads are regarded as well, the difference reduces to about 0.5dB (fig 02, on the right). When the mapping task focuses on major roads only, but takes residential areas of the whole city into account, then a large fetching radius may be necessary where dominant ring roads influence quiet areas. In principle we suggest applying a fetching radius on the “safe” side and using extra criteria for source suppression, such as the dynamic error margin. Based on consultant expertise and statistical verification, the fetching radius may still be set to a value of less than 3000m. In any case the chosen parameter should be proven against an extreme radius, using the statistical tools mentioned above. How the software applies a fetching radius for sources includes another risk. If a part of the geometry of an emitting line is found within the fetching radius, the software might take into account either the total object or, more correctly, only the part of it that is within the fetching radius. If the software does not follow the second approach, this will potentially lead to step changes in results for neighbouring receptor positions when a complete source line element drops out of consideration. This can result in poor quality indicators for the selected grid increment. The effect will occur where road elements had been digitised in long line segments, whereas short segments will show good results. The second approach, where the source line objects are cut at the edge of the circle defined by the fetching radius, might show a similar phenomena when the receptor position reaches a perpendicular distance to the road that almost equals the search radius (Fig. 03).

The situation in fig. 03 has been calculated for different distances between 50 m and 3000 m, using fetching radii of 3000 m or 5000 m. Fig. 04 shows the differences in receptor levels. As a conclusion we suggest to limit the prediction area to a maximum distance to the road of 80% of the chosen fetching radius, e.g. 2400 m for 3000 m radius. This will limit the potential error to approx. 0.6 dB. Of cause the error will be less if the source is less significant at the receptor position.

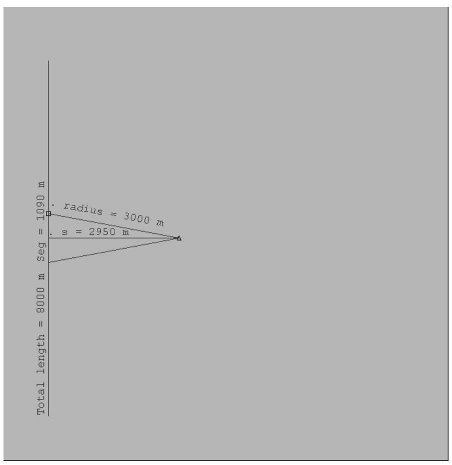

Fig. 03: remote receptor position

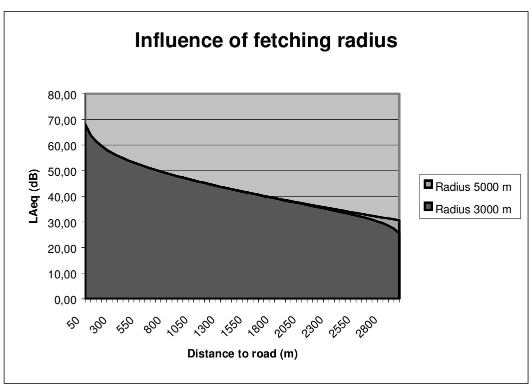

Fig. 04: Levels for 3000 m or 5000 m fetching radius

3.2 Model simplification

Simplifying geometry prior to calculation

Model simplification prior to the calculation run, has the disadvantage that different sets of model data need to be organised in parallel, especially when simplifications are introduced that are not accurate enough for in depth analysis at a later phase of the project. Sometimes it may even be advisable to simplify the polygon representation of buildings to ensure reflective properties of facades (minimum length criteria) rather then to reduce the calculation load. Extreme simplifications, such as buildings represented by single screens, should be no issue any more. In other cases it needs to be ensured that adjacent building objects are not separated by the smoothing procedure.

For objects where the z-value changes per vertex, simplification needs to work in 3-d. Erasing inner walls and combining small terraced buildings into larger units will only work for horizontal terrain.

Terrain contour lines are often consisting of a density of vertexes that is not required in acoustic calculations. This is due to the way contours are automatically generated from discrete information. Any simplification of their geometry needs to regard neighbouring contours.

Simplifying building geometry on the fly

Along the path of sound propagation many edges of obstacles will be encountered. Baring in mind, that the search for the diffraction path for many regulations includes finding an enveloping shape, e.g. like a rubber band stretched from receiver to source, it is worth to try to work on a simplified geometry during the calculation. The shape of the barrier and its distance to source and receiver may be a criterion for the suppression of the object.

Fig. 05: Test area barrier simplification

Fig. 05 shows a 1 x 1 (km²) area that had been conventionally calculated in a 10 m grid within 357s (at 1400MHz).
Next the same area had been calculated with a distance related barrier simplification. Calculation time was 253s. The difference of 1st result – 2nd result has been analysed for the 8532 receptor positions outside buildings.
Mean difference: -0.03
Standard deviation: 0.11
0.1 quantile: -0.40
0.9 quantile: 0.00

Dynamic error margin

As considered before, the fetching radius for sources should be chosen on the "safe" side. To speed up calculation a user defined "dynamic error" margin had been introduced into LimA. The idea is, to suppress unimportant emitters up to an extent that a defined error (dB) on the total result is not exceeded. So the consultant has full control over the effects of his simplification parameters. The two picture below show the result for calculation with an error margin of 0.0dB and alternatively with 1.0dB.

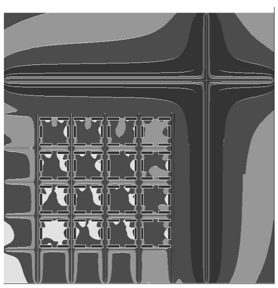

Fig. 06: Results for 0.0dB error margin

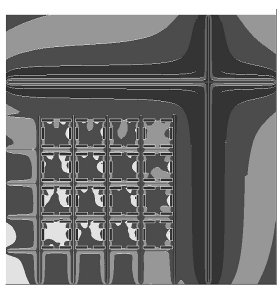

Fig. 07: Results for 1.0dB error margin

The model covers an area of 4km² and on a 1400MHz laptop the 10m grid calculation took 198s, when source neglecting was not allowed (0.0 dB error margin). For a maximum error margin of 1.0dB, calculation time went down to 32s or 0.0008s per receptor. The average error of the 40401 receptor grid positions was just 0.11dB.

Single source logic

Alternative techniques, which just look for the influence of the individual source without seeing his in the context of all neglected sources, will produce an unpredictable error that depends on the segmentation of line sources in the model. This is especially of a problem for geometry data with CAD origin.

Source segmentation

Source segmentation is another mechanism that will influence calculation speed. You may for instance increase the interval at which the angles of a ray tracing are changing or you define a longer segment length in other techniques. For the method of projection a minimum, distance related length could be chosen as well. All 3 methods will have different influence on the uncertainty related to a receptor position, i.e. how representative is the receptor position for the neighbourhood, e.g. grid cell. The subject is handled in more detail in our paper on "Implementation of Prediction Standards" [ref 5].

Representation of area sources

It is widely accepted in the regulations that the degree of detail of source representation is linked to its distance to the receptor position. When considering area sources this will imply modulo base changes in the position of substituting source elements. While it keeps the same for some receptor position, it will then be different for two adjacent receptor positions, which may even be as near as a few cm. This will lead to changes in diffraction with create unreasonable changes in noise levels for positions where almost the same results are expected. Consequently the win in calculation time is paid by an increase the uncertainty related to receptor positing. Other effects are caused when emitting areas are represented by point sources instead of line sources. This is also described in [ref 5].

4 Type of grid definition

4.1 Irregular grids

To speed up calculation it is an obvious idea to interpolate grid results from neighbouring positions that have actually been calculated. Any coloured map uses this logic per se.
It is difficult, or perhaps even impossible, to predict the error margin for the interpolated levels. Again statistical analysis, as suggested before, may give some indication.

First of all some pitfalls need to be avoided from the very beginning:
- Receptor noise levels of rough grids should only be interpolated within regions where there are no barriers and no sources.
- In some strategy small changes of receptor levels in the rough grid are seen as indication, that interpolation is adequate. Here it needs to be ensured that the noise levels for the relevant positions in the rough grid are caused by the same source/barrier constellations.
Receptor results for non regular grids, such as grids

adjusted to the source and barrier geometry, are not always appropriate for interpolation as potential reflection effects may be ignored and a diminishing diffraction effect may cause peak values at some distance to a barrier, which are not represented in the interpolation.

Fig. 08 will illustrate this.
It shows a 400 m x 400 m area.
The two buildings on the left are placed on a slight slope and are protected against road noise by the barrier construction to the left of the road.

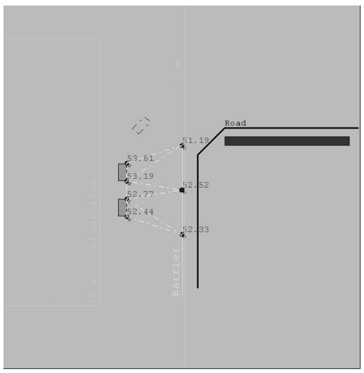

Fig. 08: irregular triangular grid net

An irregular triangular net is set up between barrier and buildings. At the vertex positions receptor results are within a range of 51.2 – 53.8 (dB), all in the same level class of 50-55. Interpolated graphic colour presentation would thus be homogeneous for the 60m region between barrier and buildings.

A conventional 1 m grid calculation shows a different situation (fig. 09).
Almost 50% of the area is exposed to noise levels in the class of 55-60 (dB) with the peak are surrounded by the 56dB contour.

Fig. 09: 1 m grid results

Fig. 10: extra reflector

Next a further building is introduced into the model (Fig. 10). It has reflecting façade properties. Due to its position, non of the receptors defining the irregular grid before are effected and results are the same as in fig. 08. The 1m grid results now show that almost the entire area under consideration is exposed to noise levels of a different level class.

So there are some limitations to the introductions of irregular grid calculations. Certainly net vertexes shall also be inserted in free field situations, even when this is not indicated by changes in noise levels. For an irregular grid net that orientates on the model geometry, fixed grid positions may be used as random check positions for uncertainty analysis.

4.2 Rectangular grids

To justify the chosen width in a rectangular grid calculation, the receptor positions need to be varied and the average of the 4 neighbouring results in X,Y can be compared against the centre position.

5 Summary

The uncertainty in calculated noise levels, which are caused by model simplification as well as calculation acceleration or chosen grid width should be evaluated by statistical tools, either to define mean values and standard deviation or quantile (percentile) values. Typically the comparison will be performed for a randomly chosen subset of receptor positions. The comparisons should be considered for the original model and conservative calculation parameters (fetching radius etc.) against a simplified model and the finally chosen calculation parameters.

References

[1] D. Manvell, H. Stapelfeldt, 'Software Strategies in Noise Mapping'. *Internoise 2003,* Korea

[2] WG-AEN, 'Good Practice Guide for Strategic Noise Mapping…'

[3] DIN 45687, 'Software products for the calculation of the sound propagation outdoors - Quality requirements and test conditions'

[4] DIN 45682, 'Sound immission maps'

[5] E. Hartog van Banda, H. Stapelfeldt, 'Implementing prediction standards in calculation software – the various sources of uncertainty