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Self-adaptive grids for noise mapping refinement

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ABSTRACT

Noise maps are usually represented as contour or isolines maps describing the sound levels in a region. Using this kind of representation the user can easily find the noise level assigned to every location in the map.

But the acoustic calculations behind the map are not performed for every single location on it; they are only performed in a grid of receivers. The results in this calculation grid are interpolated to draw the isolines or contours. Therefore, the resolution of the calculation grid and the way it was created (rectangular, triangulated, random…) have an effect on the resulting map.

In this paper we describe a smart iterative procedure to optimize the quality of the map at a really low additional computational cost, using self-adaptive grids for the acoustic calculations. These self-adaptive grids add new receivers to the sampling grid in those locations where they are expected to be more useful, so that the performance at the output of the interpolator is enhanced.

Self-adaptive sampling grids can be used for minimizing the overall error of the map (improving its quality), or for reducing calculation times, and can be also applied selectively to target areas or contour lines. This can be done by the user customizing the maximum number of iterations, the number of new receivers for each iteration, the target isolines, the target quality…

1. Introduction

A noise map is a graphic representation of the sound level spatial distribution in a region, which is usually represented using contour lines. Nowadays, calculation tools based on noise models are widely extended for such maps, because of their high accuracy, the lower cost and the possibility they provide for the evaluation of different scenarios.

The acoustic calculations are performed in a grid of receivers distributed all over the location; this is a sampling calculation grid. Traditionally, this grid can be defined as a rectangular, triangulated or random grid [1].

It is necessary to calculate the sound level (Lk), usually A-weighted continuous sound pressure level (dBA), for every point (k) in the grid. This is performed according to a specified acoustic model, usually with the help of some commercial software (Cadna, INM, Lima…). The uncertainty of the noise level calculations and models has been widely studied [2–16], and is beyond the scope of this paper.

A full map for the whole area is obtained by spatial interpolation of the results in the grid. There are several interpolation algorithms that can be used to draw the map: IDW, kriging… [1,17,18]. The techniques for spatial interpolation can be divided into two main groups; deterministic and geostatistical interpolators. Deterministic interpolators create a surface from measurements based on the extent of similarity (inverse distance weighted) or the degree of smoothing (radial basis functions) of the data. Geostatistical interpolators (kriging) use least-squares regression algorithms to create a statistical model for the observed points, which allows the prediction of noise levels at unobserved (uncalculated) locations, leading to better results when applied to noise mapping.

Other acoustic considerations can be taken to improve the local performance of the interpolation process, for instance near barriers, or near sound sources [5].

After interpolation, it is necessary to make a classification in ranges (usually 5 dB ranges [19]), to get the isolines of the map. Fig. 1 shows the results (L_k) at the receivers in the grid (k), and the isolines obtained after interpolation and classification. Fig. 2 shows the full process of drawing up a noise map.

Obviously, the resolution of the calculation grid and the number of receivers in it have an influence on the concluding map. If we select a high-resolution grid, the isolines will be more accurate and precise.

Outdoor noise simulation software can perform all this process, making it all very easy for the end-user. The practitioner will have to select the size of the grid, as a compromise between the accuracy of the map, and the calculation effort.

In this context, it is a common practice when noise mapping large areas, to approach the calculation in two stages. The first

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Fig. 1. Contour lines obtained by interpolation of sampling grid.

stage uses a coarse grid (for instance 30 × 30 m), to find the areas of interest. The second stage applies a higher resolution grid (usually 10 × 10 m), which is only applied to specific areas of interest, usually in populated areas. Occasionally thinner grids can be applied [19].

Following a similar strategy, the INM uses irregular sampling grids for noise mapping refinement [20].

The main objective of this paper is to present an efficient method that substantially improves the quality of a noise map (the precision and accuracy of its contour lines), by reducing the error derived from the calculation grid, and the interpolation + classification process, at a very low additional computational cost. This method estimates the uncertainty of the isolines in the map, and dynamically adapts the grid for the acoustic calculations, creating what we have denominated self-adaptive grids.

2. Methodology

The self-adaptive grids method is based on the following basis: The isolines are the supporting objects in a noise map, so that if the isolines are perfectly drawn, the map is completely perfect.

Assuming that this is true, we can derive that the error at any location between two consecutive isolines will be zero. So, the uncertainty in a noise map is produced by the random deviations between the noise level expressed by the isoline and the real value at each location on that line (Fig. 2).

Bearing this in mind, we can minimize the map's uncertainty by setting the focus on finding the correct location of the isolines, instead of getting information about the whole area. We must extend the grid of receivers to perform calculations at those locations where we can extract really useful information, avoiding useless receivers.

The idea behind this algorithm is to utilize uncertainty sampling for data exploitation [21], which is a widely extended concept in the field of active machine learning [22].

2.1. Uncertainty in noise map isolines

When we finally get a noise map, it will have several contour lines. If the accuracy and the precision of the map is optimal, these isolines would have been drawn at their correct position. The actual distribution of the error along the contour lines will cause uncertainty, as the true value for every position on the line is not known.

For instance, if the uncertainty of the "isoline 50 dB" is ±1 dB for a level of confidence of $X\%$, it means that the true value along the $X\%$ of its length lies within the interval [49 dB,51 dB], therefore, the error on the $X\%$ of the length of the isoline will be lower (or equal to) than 1 dB. Thus we can consider that the isolines are the supporting objects in the noise map, and we can use them to derive the quality of the map.

Following the GUM [23]) definitions, we can derive that for the calculation of the uncertainty it is necessary to establish a 95% confidence interval for the error on the isolines. The uncertainty of the concluding map will be affected by several factors like the quality of the input data [2], the acoustic model used for the calculations [11], the propagation of the uncertainty through the model [8]... On the other hand, the calculation grid and the interpolation process will also influence the uncertainty of the map, their being factors that the user can customize. Quantifying this contribution can be very important, as it can be minimized without changing the data inputs to the model. For instance, a very simple way to do it is by just using a thinner calculation grid, including more receivers. However, it would considerably increase the computational effort and the calculation times [5,14].

In this paper we set the focus on the influence of the sampling grid, as the objective is to create an optimized self-adaptive grid that can improve the quality of the map at a low computational cost. All the other contributions to uncertainty of the calculations have been neglected, so we will consider that the results L_k, calculated by the acoustic model for the sampling grid, are true values.

2.2. Measuring the quality of the map

Although it is not strictly mandatory for running the self-adaptive grids algorithm, it was considered quite valuable to define an indicator that describes the quality of the map, as it can be used for taking decisions during the execution of the algorithm. This indicator will also be used for the assessment of the results, as a comparison of the quality of different maps.

There are several indicators that could have been selected: mean square error, differences of quantiles [24], but we preferred to use the uncertainty on the isolines as described in [25], and summarized in this section, because it more properly weights the bias and the variability along the isoline, taking into account the number of observations. Even in the event of the conditions for this parametric approach not being met, it gives a good measure of the quality of the map that can be used for comparison purposes, or to control the flow of the algorithm.

After having drawn up the map, we will have several contour lines in 5 dB ranges (usually). We will consider a single contour

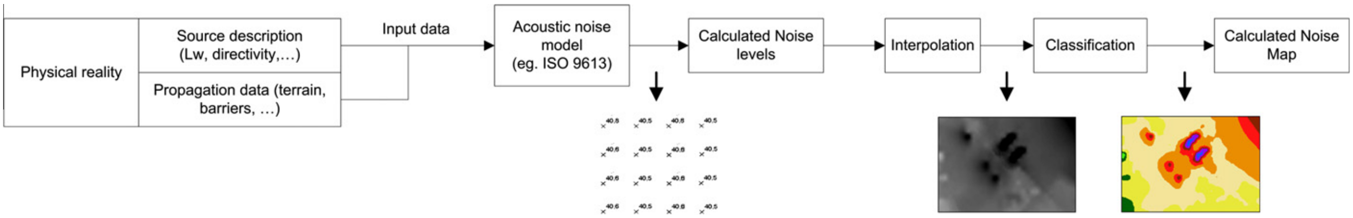

Fig. 2. Process of drawing up a noise map.