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NOISE CONTROL FOR A BETTER ENVIRONMENT

Benchmark tests to decide the best technology to be applied in large strategic noise mapping

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ABSTRACT

Software for noise prediction is an invaluable tool to analyze any acoustic situation. From detailed noise studies in industrial plants including calculations of up to a high number of reflections to large scale noise maps for hundreds of km2, almost every situation can be covered by these software packages. It can be stated that even with best available hardware and software technology it is necessary to use special acceleration techniques and approximations if large scale noise maps need to be calculated. The uncertainty caused by the applied acceleration techniques needs to be qualified by any software product to support the decision about what is acceptable. A thorough analysis as starting point of a noise mapping project allows to optimize the procedure in relation to calculation time and acceptable uncertainty. This contribution presents real calculation examples used to illustrate all relevant steps of the optimization process, including hints about the hardware used to support the calculations. In addition, the influence of the variation of critical calculation parameters, on both accuracy and calculation time, is shown for real scenarios.

Keywords: Software, Benchmark, calculation speed, uncertainty, accuracy.
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1 INTRODUCTION

Noise mapping has become an important tool and starting point to integrate the noise aspect in all technical and political decisions. A practical example is the implementation of the European Directive about environmental noise 2002/49/EC which bases all plans against noise on the calculation of noise maps of large areas such as complete cities and communities or even countries. This situation has pushed the development of noise prediction software packages that take advantage of the best hardware technology available.

It is obvious that even using the latest hardware and software technology, calculations could be extremely time consuming and not necessarily more accurate. Therefore, the use of acceleration techniques available in the different software packages is key to obtain reliable results faster only if the decrease in the accuracy can be estimated and therefore, controlled.

This contribution discusses the impact on the calculation results of several acceleration techniques that have been tested in a pilot area of a city. Next to that, a complete project has been calculated with two powerful hardware configurations and results have been compared.

2 PROJECT DESCRIPTION

A complete city has been used as test project. The area of the city has approximately 8,5 km x 8,5 km, including 4832 buildings and 380 km of roads distributed over 4913 roads / streets. The calculation method used was CNOSSOS-EU.

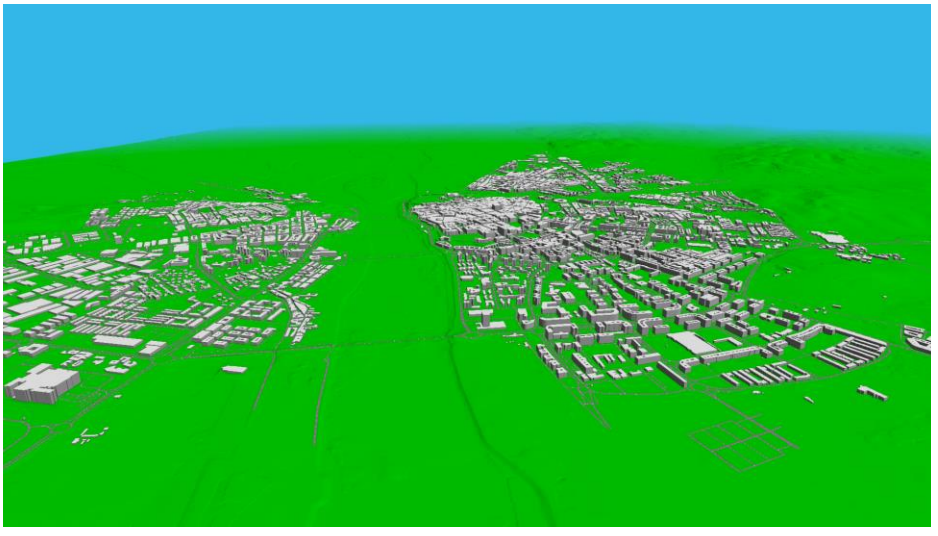

Fig. 1 – 3D View of the project area

Before performing the computation of the whole city, a pilot area has been selected for testing different acceleration techniques. As the acceleration techniques are influenced by the nature of the tested area, the selection of a representative pilot area is critical. The size of the pilot area has 3,8 km x 2,5 km and combines an open area with a denser city area.

3 THE UNCERTAINTY DUE TO THE SOFTWARE CONFIGURATION

The pilot area has been used to test different acceleration techniques. The software strategy is critical to avoid unnecessary or not relevant calculations and therefore obtain results faster without a strong impact on the uncertainty. It must be clear that the evaluation of the influence of the software configuration in the accuracy is related to the deviation from the “exact” calculation by using the applied calculation standard. In that sense the underlying calculation method defines the “truth”, and any deviation caused by the different configuration decrease the accuracy.

The approach follows the method described in the DIN 45687 which allows to evaluate the uncertainty in a noise map hat is caused by the acceleration techniques. This procedure consists of the following steps:

- The calculation must be carried over a minimum of 20 fixed receiver points which are distributed statistically over the complete area. During the tests **500** receivers have been used.
- The level at these points is calculated with a “reference configuration” where no acceleration techniques are applied. The reference configuration must be standardized beforehand, as it is the basis of the uncertainty calculation.
- Then the configuration including the acceleration techniques is applied and the calculation is repeated.
- The differences between the two calculated values are sorted out and the following statistical information is given: standard deviation, mean value and the 0.1 and the 0.9 quantiles defining the limits of the uncertainty interval according to DIN 45687.

The relevant acceleration settings under test are explained below and the results of the tests are discussed:

3.1 Maximum Error and Projection

The maximum error allows to set a value in such a way that sound sources whose contribution to the level at the receiver point is negligible will be disregarded in the calculation. Therefore, the larger the maximum permissible error is, a shorter calculation time will be required.

Calculating the level at a receiver is now a two-step procedure. With the first step the contribution of all sources inside the search radius is calculated neglecting all attenuations but the ones caused by geometrical dispersion. These contributions are sorted out and the real calculation is performed including the sources with descending order. After each adding up a new contribution, the sum of the contributions of the remaining rest is compared with the defined value – if it is smaller, the calculation can be stopped, because this sum of contributions of the remaining rest is related to free field propagation and their real contribution will be smaller with large probability.

On the other hand, the projection modifies the segmentation of line and area sources in such a way that a pre-segmentation is applied, depending which parts of the source are screened and unscreened and applying the distance criterion. This improve the results at receiver points especially if there are only few sources. With regards to this setting, the specific situation – including many sources contributing from all directions – makes the projection technique not relevant while the calculation time decreased dramatically when deactivated.

The reference configuration set the maximum error to 0 dB and with projection activated, which means that the acceleration technique has not been used. In the project configuration, the maximum error was set to 0.5 dB and the projection was deactivated. The combined effect of the acceleration techniques Max. Error and Projection reduces the calculation time in approximately a 76% while the standard deviation is 0.2 dB.

Table 1 – Statistical analysis for Max. Error and Projection

Configuration of calculations	Reference	Project
Max. Error (dB)	0.0	0.5
Projection. Line Sources	1	0
Projection. Area Sources	1	0
Calculation time:	**47,891 s**	**11.204 s**
Statistical analysis:		
Quantil q0.1:	-0.2	
Quantil q0.9:	0.1	
Mean:	-0.0	
Standard deviation:	0.2	
Minimum:	-1.3	
Maximum:	1.3	

3.3. Grid interpolation

The interpolation allows to set a value n*n, and the level calculation occurs starting at each of the (n+1) grid points as specified on the grid spacing, as well as at the center point of each rectangle delimited by those four points.

There are two conditions that must be met in order to successfully interpolate the grid:

1. The difference between the largest and the smallest level calculated at the four corners of the rectangle is, at most, equal with the specified maximum value (default value: 10 dB). The default value of 10 dB ensures that - in case of significant extra attenuation between the corners (e.g. by large obstacles) - a further subdivision occurs.

2. The mean level calculated from the levels at the two corner points of each diagonal shall not differ from the level at the center point by more than the specified maximum deviation (default value: 0.1 dB). This condition must be fulfilled for both diagonals. The default value of 0.1 dB is - in general - exceeded if additional attenuations on the diagonals between the corners and the center are caused, e.g. by a screening obstacle.

When these conditions are fulfilled, the interpolated values inside the rectangle match sufficiently with the real values and the levels at the remaining grid points inside the rectangle are interpolated from the levels calculated at the four corner points. If any of these conditions is still not met, a further subdivision occurs recursively until they are fulfilled, or all grid points have been taken into account in the calculation based on the grid specification.

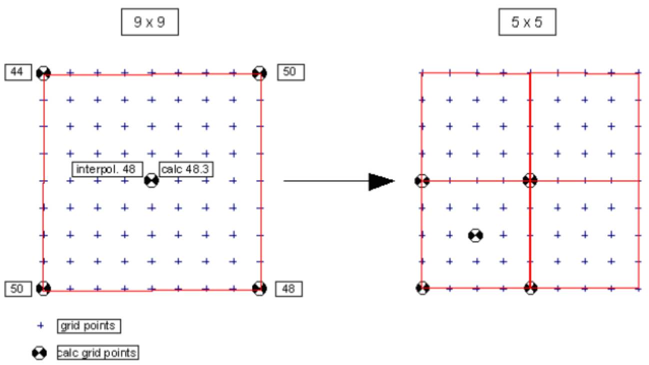

*Fig 2 – Transition from a rectangle of size 9*9 to size 5*5 when a condition is not fulfilled*

In the case of the grid interpolation, the calculation of both grids (with and without interpolation) has been performed and the calculation times are shown. Then, a specific uncertainty test has been carried out by placing automatically receiver points along a selected iso line (here 65 dB).

Fig 3 – *Set up for the statistical analysis of grid interpolation. Automatic placement of 750 receivers at the 65 dB iso-line*

The uncertainty analysis compares the value for the generated contour line with the real results at the receiver points. Results are shown in the following table:

Table 2 – Statistical analysis for grid interpolation

Configuration of calculations	Reference	Project
Grid Interpolation	(none)	17 * 17
Statistical analysis:		
Quantil q0.1:	-0.5	
Quantil q0.9:	0.3	
Mean:	-0.0	
Standard deviation:	0.5	
Minimum:	-4.2	
Maximum:	4.1	

The difference between the grid with and without interpolation is shown below. The differences are in the range of -0.1dB to 0.1 dB all over the grid. These small differences are present where the interpolation has been successful. The area where most of the obstacles (buildings) are present has no differences as the software has probably applied further subdivisions until the conditions were fulfilled.

*Fig. 4 – Difference grid (no interpolation vs. interpolation (17*17))*

4. BENCHMARK RESULTS FOR DIFFERENT HARDWARE CONFIGURATIONS

The next step after analyzing the statistical uncertainty of the calculation settings is the application of the selected configuration to a real project. Here, not only the acceleration techniques implemented in the software but also the hardware used is relevant, as there might be software implemented features that are designed to take advantage of the computing power of it.

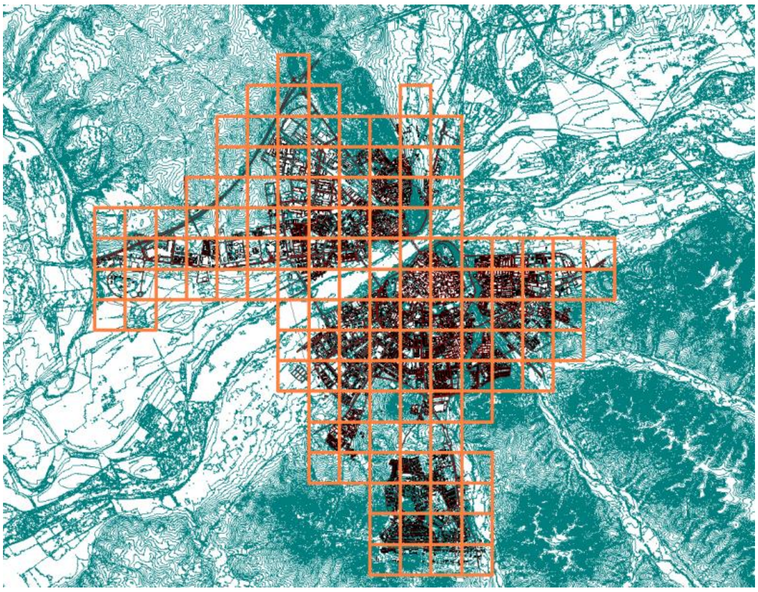

Fig. 5 – Segmentation of the calculation area in smaller tiles by using the PCSP technique

To this end, the calculation area has been divided into smaller tiles of a size of 500 x 500 m. These tiles will be loaded automatically one after another for calculation into parallel calculation processes. This technique allows the RAM to work without hard disk access while the software automatically manages the distribution of segments over the calculation processes. The so-called Parallel Segmented Controlled Processing (PCSP) has been tested on two hardware configurations:

- **Single workstation:** i7-8700k, (6 core, 12 threads) processor, 16 Gb RAM, 512 Gb SSD
- **Calculation cluster:** 8 x Intel Xeon E3 (4 core, 8 threads), 8 Gb RAM, 1 Tb HDD each

The project has been calculated twice on each hardware applying different calculation settings:

<u>Calculation setting "Slow"</u>		**<u>Calculation setting "Fast"</u>**	
Search Radius:	1000 m	Search Radius:	1000 m
Maximum Error:	0 dB	Maximum Error:	0.5 dB
Projection of Line Sources:	Activated	Projection of Line Sources:	deactivated
Triangulation:	Activated	Triangulation:	deactivated
Max. order of reflection:	1	Max. order of reflection:	1
Grid interpolation:	deactivated	Grid interpolation:	17*17

Fig. 6 shows the speed of computation as a sum of all the calculation times from each tile. Compared to the single workstation, the 8-PC cluster represents 32 vs 6 real cores. Even though the i7-8700K is 5 generations newer than the older Xeon E3 CPUs, the latter have higher clock speed, allowing the cluster to be about four times faster than the single workstation.

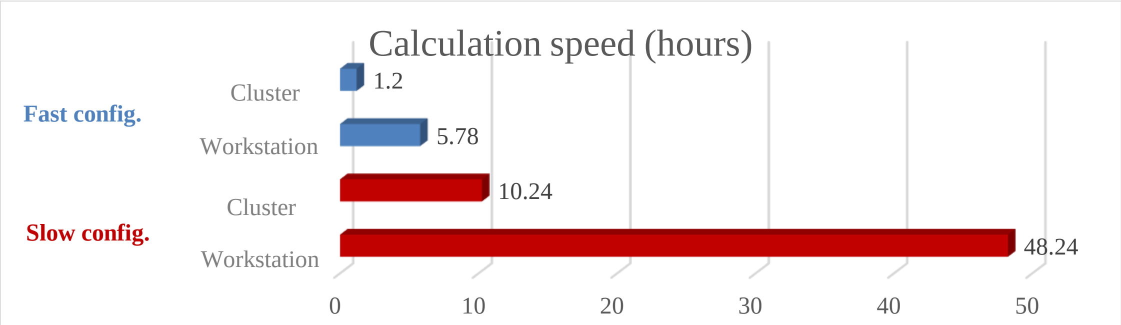

Fig. 6 – Single workstation vs calculation cluster calculation speed comparison, for both fast and slow calculation settings

However, input and output via network share usually slow down the batch calculation in the cluster. Reasons are that the full project file needs to be loaded via network even in the case of the outer tiles with very small calculation load, and that the access to the file is restricted to one PC at a time. In the case of the single workstation, the project is within a local batch directory on an internal SSD. Fig. 7 shows the "effective calculation time" – real calculation time from the first tile to the last one - which allows the user to get the project done.

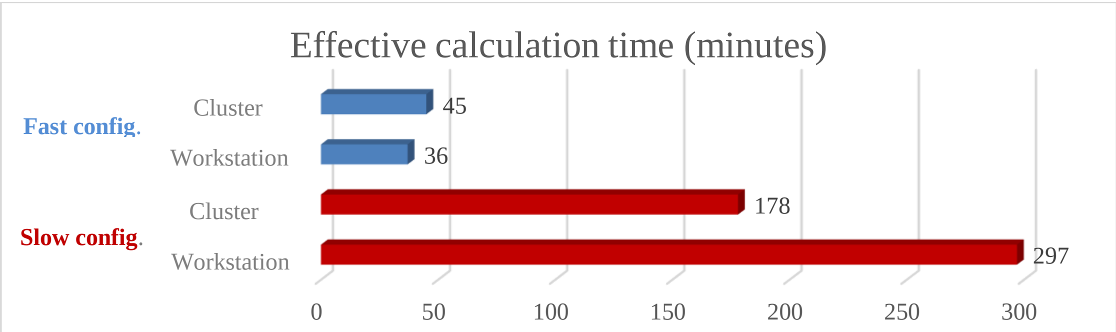

Fig. 7 –Single workstation vs calculation cluster effective calculation time comparison, for both fast and slow calculation settings

As an example, while the pure calculation speed, using the fast configuration on the cluster from (Fig. 6) indicates a speed-up factor of 4, the time needed for completing the whole batch calculation has no practical difference with the single workstation (Fig.7). This effect is not only caused by the SSD, where the mean loading time of a tile was 3 seconds, but also the fact that even if one of the batch processes had to wait before it could load the next tile, all the CPU cores would perform on the other processes without interruption or idle status. In the case of the cluster, any PC that finished its job needed to wait the load process of the current tile before loading a new one.

5. CONCLUSIONS

The calculation time depends on the type of calculation and the tasks the user wants to execute. Generally, a higher CPU clock speed will almost linearly accelerate the calculation speed if no other factors are taken into account. On the other hand, if multi-core processors are used, acceleration is achieved by parallelization. Two things need to be considered here. First, the parallelization of a calculation implies an additional overhead for the distribution of the job parts and the consolidation of the results. Secondly, the higher the number of cores simultaneously working on a calculation, the more “friction losses” will occur. If hard disk access must be considered, then SSD disks accelerate dramatically the read & write tasks so the effective calculation time can be close to the performance of a calculation cluster.

The uncertainty analysis according to DIN 45687 is a powerful method to determine the influence of acceleration techniques allowing to get the influence of accelerating settings on the accuracy and to decide about the best suited calculation configuration. It avoids unnecessary time-consuming calculation tasks while the result is perfectly suited to take decisions and design action plans.

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