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SIMPLIFIED MAPPING ALGORITHM FOR FAST SURVEYS, REQUIRING MINIMAL INPUT DATA

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Abstract

Whilst currently available programs for computing noise maps become even more complex, there are cases where the usage of highly detailed algorithms and procedures is meaningless, because the input data for such processing is simply not available. So it is often seen that a very complex and theoretically very accurate simulation system is providing objectionable results, because the user had to "guess" for all the required input data which were not known.

The paper describes the algorithms employed in the program Citymap 3.0. This software is very simple to use, requires just a minimal geometrical description of the site, of the sources and of the receiving areas. The algorithms employed are stripped-down versions of the computational methods currently mandatory in Italy, after the EC directivity on environmental noise has been converted into Italian Law DL194 of 19/08/2005. Namely, the propagation algorithms are fully compliant with NMPB-Routes-96 for the road noise, with Reken-en Meetvoorschrift Railverkeerslawaai '96 for the railway noise, and with ISO 9613/2 for industrial sound sources. The program imports easily geometrical data from most CAD and GIS packages, and asks only for minimum information about sound sources and receivers. Thank to a new, fast computational engine, the program can map with high spatial resolution large areas, even in presence of a lot of obstacles and on arbitrarily-shaped terrains. As the variance due to introduction of guessed input data is reduced, the results are often more reliable than those of theoretically more accurate models, which are usually very sensitive to errors in the input data.

Some comparative results are presented, verified by measurements in the field, for demonstrating the above assertion.

INTRODUCTION

This paper reports on the development of a new version of the noise mapping software Citymap. This software was developed on 1996-1996, thanks to the DISIA project “acoustical re-healing of urban areas”, driven by the Italian Ministry for the Environment. The result of this project was a huge collection of experimental measurement of noise emission of vehicles running on Italian roads and railways, which constituted the “emission data-base”.

Also two accompanying software tools were developed, Citymap for noise mapping on large areas, and Disiapyr for detailed simulation of noise reduction devices [1,2].

The first program was employing only wide-band data in A-weighted scale, and was requiring only minimal information about geometry and surface properties. The second program operates with the Pyramid Tracing algorithm [3], computes everything in 8 octave bands (63 Hz to 8 kHz), and requires detailed geometrical modelling and octave-band values of absorption coefficient and sound reduction index of surfaces.

These two programs, packaged with other utility tools (a CAD application, a Material Manager application and a Source Manager application) were the basis for the DISIA package: this is a complete sound modelling system released freely by the Italian Ministry for the Environment for public administrations (municipalities, schools, universities, etc.). The package has never been sold to privates or professionals, who were forced instead to purchase very expensive commercial software packages, which were not so easy to employ, and which did not contain an accurate sound emission data-base carefully matched with Italian vehicles and style-of-driving.

So the DISIA package was the “reference” noise simulation software in ITALY, and its technical features were mandatory by law (D.M.Amb. 29 November 2000), although the law did allow the usage of other software packages, provided that they did manage to provide the same technical capabilities.

This situation did change suddenly in August 2005, when a new law (DL n. 194 of 19/08/2005) did adopt partially the contents of the EU directive 2002/49/CE. This law mandates for the noise mapping software to adhere to three old technical standards for computing the noise immission produced by road traffic, railways and industrial sources [4,5,6].

Of consequence, the very simple and practical Citymap program, which in the meantime did evolve up to the latest version 2.4, cannot be used anymore, because its internal computational algorithms are not compliant exactly with those of the three mandatory standards outlined above.

On the other side, the Italian Ministry for the Environment is not supporting anymore the development of Citymap since several years. So this job has been taken over by LAE – the Laboratory for Acoustics and Electroacustics born in Parma in 2005, thanks to a grant issued by Regione Emilia-Romagna as part of their PRIIT scheme for supporting advanced research and technological transfer.

The Citymap program has been completely rewritten by scratch, with the following goals:

- Significant improvement of computational performances;
- Compliance with the “new” standards made mandatory by the law.

The first goal has been fully achieved, rewriting the full program in C++ language and employing numerically-optimized subroutines which provide a significant performance boost on modern processors.

The original program did suffer of some limitations: it was possible to easily associate the emission properties to the geometrical entities (road traffic, railway traffic, noise emission of industrial sources), but the program did not have any tool for inserting or modifying the geometrical entities, so it was mandatory to perform any geometrical modification inside an external CAD program, and to re-import completely the geometry every time a small modification was done.

As the transfer of geometrical information between the CAD package and the Citymap software was done by means of a simple DXF file, containing only very basic entities (polylines), every time the emission data had to be re-attached to the geometrical entities. Albeit this fact is similar also for many commercial packages, it was decided to introduce in Citymap a set of basic CAD tools, allowing for editing the imported entities, to insert new ones, and to perform automatically advanced operations such as transforming a 2D plan into a 3D model, by automatic detection of buildings, obstacles and ground altimetry.

Of course the program was also made compliant to the 3 international standards [4, 5, 6], forcing the propagation laws to comply strictly with those of the standards. However, 2 of these three standards also contain a part which refers to sound emission values: the choice here was to not employ the emission values coming from the NMPB-Routes-96 and Reken-en Meetvoorschrift Railverkeerslawaai '96. In fact, these emission values are “correct” for French road vehicles and for Netherlands’ train, which revealed to be quite different from the noise emission of Italian vehicles.

As we have this very detailed Italian emission data-base, perfectly matching the real situation of noise emission in Italy, it appeared illogic to employ instead data-bases of noise emission values which are mismatched with the reality in Italy, and being forced later to “calibrate” the software altering the traffic data, the speed, or other quantities, in order to cause the software to produce results matching the experimental measurements.

So the new version of Citymap is “hybrid”: it retains the usage of the Italian emission data base, which is based on a collection of values of SEL (Single Event Level) for the transit of several types of vehicles at different speeds, with different types of road surfaces or rail tracks, and at different slopes. But then it adopts the international standards with reference to the computation of the decay with distance, the effect of the ground and of the obstacles.

In the following chapters a quick description of the internal computational algorithms is given, followed by a description of the usage of the new program in a test case, in which it was possible to compare the results with those coming from detailed measurements performed employing an innovative electroacoustical technique and with the Pyramid Tracing program Ramsete [3].

ALGORITHM

Each road or railway is represented by a 3D polyline, drawn on a specific layer (named respectively ROADS and TRACKS). Each polyline is constituted by several segments, each being characterized by its two extremes and by its width.

Inside Citymap, suitable traffic data are attached to each of these polylines. This means the number of vehicles and their speed. Each road or railway has also a given width, slope, height of surrounding buildings, and type of surface.

First of all, starting from the values of SEL measured at 7.5m from the source, the emission equivalent level is computed:

$$L_{eq,7.5m} = 10 \cdot \lg\left[\sum_{i=1}^{5}\left(10^{\frac{SEL_i + \Delta L_{asfalto,i} + \Delta L_{pendenza,i}}{10}} \cdot \frac{N_i}{16 \cdot 3600}\right)\right]$$

The above formula is for road vehicles (there are 5 types of vehicles) and for the day period (16 hours, from 06 to 22).

For trains, the SEL emission values are normalized to a length of the train equal to 100m, and there are just three types of trains, so the formula becomes:

$$L_{eq,7.5m} = 10 \cdot \lg\left[\sum_{i=1}^{3}\left(10^{\frac{SEL_i + \Delta L_{binario,i} + \Delta L_{pendenza,i}}{10}} \cdot \frac{N_i}{16 \cdot 3600} \cdot \frac{L_i}{100}\right)\right]$$

The emission value for industrial sound sources, instead, is entered directly.

Once the emission value is obtained, the program computer the propagation to each of the “listening” points, which can be manually positioned, or automatically generated over a grid, which can follow the ground altimetry. In each receiving point the contributions of all the segments of all the sources are summed energetically, producing a total immission level.

If the segment being computer is longer then half the distance to the receiver, the segment is subdivided in two, and this check is done recursively. This way, it is possible to substitute a single point source at the centre of each segment, having a sound power L_W equal to:.

$$L_W = L_{eq,7.5m} + 10 \cdot \lg(2 \cdot \pi \cdot 7.5 \cdot L)$$

It is now possible to compute the free-field propagation up to the receiver::

$$L_{eq,d} = L_W + 10 \cdot \lg\left(\frac{e^{-\beta \cdot d}}{4 \cdot \pi \cdot d^2}\right) = L_{eq,7.5m} + 10 \cdot \lg\left(\frac{\pi \cdot 7.5 \cdot L}{2 \cdot \pi \cdot d^2} \cdot e^{-\beta \cdot d}\right)$$

The proper choice of the value of β depends on the compliance with the international standard being considered, and is done automatically by the software according to the Italian law.

Also the shielding effects due to obstacles have to be computed, providing an attenuation DL which depends on the screening number z. The details for these computations for the three different types of noise sources are containing in the international standards [4, 5, 6].

EXPERIMENTAL VERIFICATION

The measurements employed for validating the new Citymap program are the same already employed for checking the accuracy of the pyramid tracing algorithm for outdoor computations [3]. The traditional MLS technique was employed [7], making it possible to measure the transfer function between the signal emitted from a loudspeaker and the signal received by a microphone, excluding any influence from the background noise.

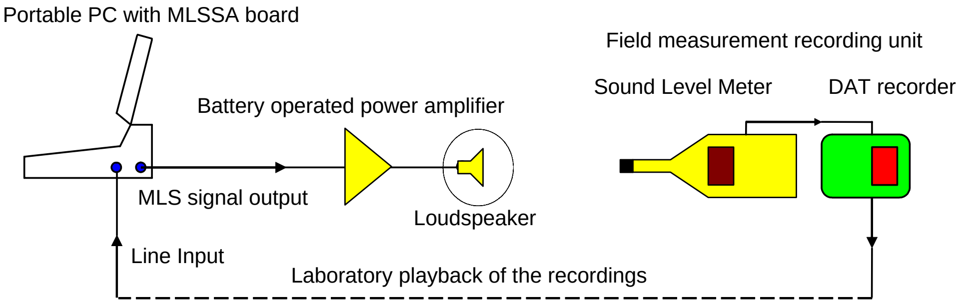


Figure 1 - Sketch of the measurement set-up

After recording one minute of MLS signal in all measurement points, the DAT recordings were played back, and re-recorded on the same computer employed for generating the test signal, ensuring to maintain closely matched clock (as required by the MLS method).

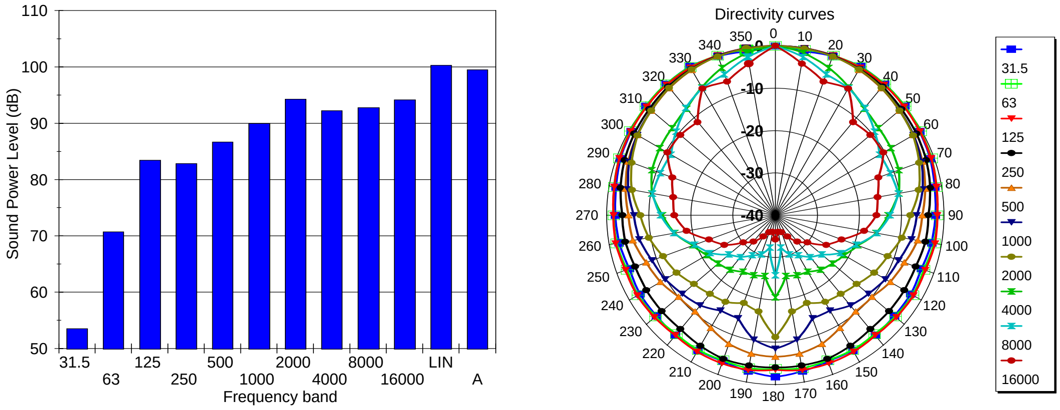


Figure 2 – Sound power level and directivity of the sound source

The measurements were performed inside the campus of the University of Parma, in front, between and behind the buildings of the Engineering faculty, as shown on the following aerial photo.

Figure 3 – Aerial view of the site and of the measurement section, and 3D model employed

The loudspeaker was located on one side of the measurement section, pointed towards the buildings. 13 receiving positions were selected along the measurement section, with a spacing of 10m.

The test involves propagation above two different soils (asphalt and grass), and reflections over glass-and-concrete facades.

The Citymap model was employing a simplified 2D geometry – only the polylines representing the buildings were drawn at an height of 8m. Instead Ramsete did employ a complete 3D model of the site, drawn employing 3DFACE entities, as shown in the following figures.

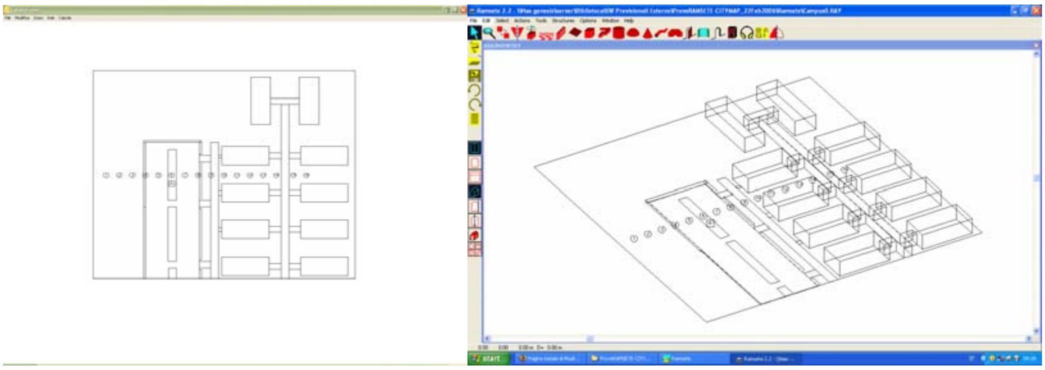
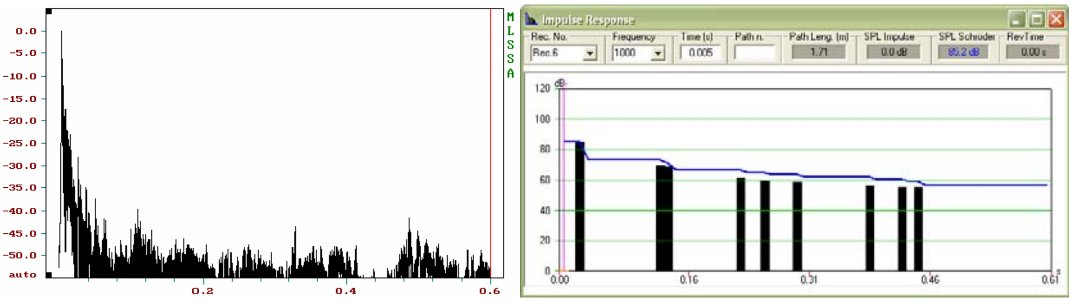


Figure 4 – 2D model imported in Citymap 3 and 3D model imported in Ramsete

COMPARATIVE RESULTS

In Ramsete three different accuracy degree were considered: without diffraction, considering only first order diffraction, considering also second order diffraction, and without limits on the order of diffractions. In Citymap the standard accuracy was selected (1st order diffraction).

First of all, with Ramsete it is possible not only to compute the total sound level, but also the impulse response, showing the discrete reflections. This was compared with the experimentally-measured impulse response, as shown here:



Rec. No.: Rec.6
Frequency: 1000
Time (s): 0.005
Path n.:
Path Leng. (m): 1.71
SPL Impulse: 0.0 dB
SPL Schroder: 85.2 dB
RevTime: 0.00 s

Figure 5 – comparison between the measured impulse response and the one computed by Ramsete

The following chart compares the experimental measurements with the results of the simulation conducted with Citymap, and the four simulations conducted with Ramsete.

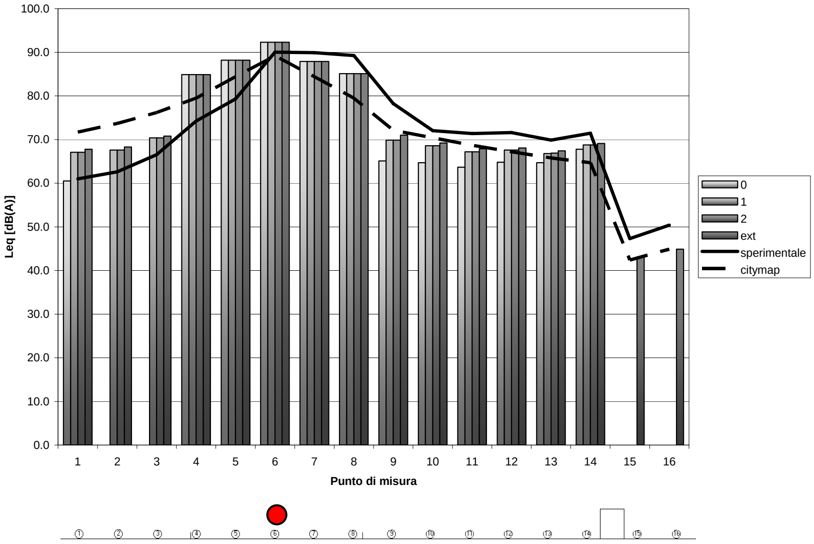


Figure 6 – Measured and simulated sound levels along the measurement section

It can be observed that Ramsete managed to provide reasonable values for the latest two points, completely shielded behind the buildings, only employing the infinite-order diffraction algorithm, which is terribly slow.

Generally speaking, the accuracy of Citymap resulted perfectly comparable with that of Ramsete, but the result was obtained with much less effort and in shorter time.

Finally it must be pointed out that Citymap is part of a new computational platform which can be run on any hardware and operating system (Windows, Linux, OSX, etc.), and which includes advanced graphical interfaces capable of provide colour noise maps plotted over the background plan of the site, as shown here:

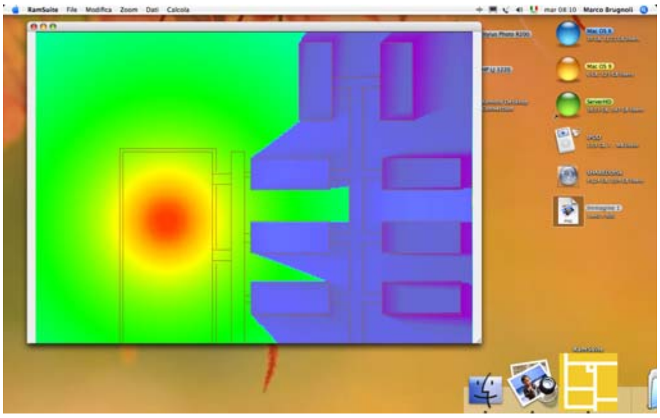


Figure 7 – Results of the noise mapping obtained with the MAC OSX version of Citymap

CONCLUSIONS

In most cases detailed geometrical data or information about the acoustical properties of the surfaces are not available. Employing "accurate" computation schemes appears to be not only difficult, but it can even result in large errors. In all these cases, a simplified algorithm is more effective for providing approximate, but reasonable, results. This goal was already available with the previous version of Citymap, but it was necessary to modify it for making it compliant with international standards made mandatory by the new Italian law. During the upgrade, the software has been speeded up and made more versatile.

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