Global sensitivity analysis of a noise mapping model based on open-source software

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ABSTRACT

When performing regulatory noise mapping, many input data are missing or incomplete. Operators must then work to complete this data by prioritizing information sources and parameters to the detriment of others. It is therefore useful to know the sensitivity of the noise model to input parameters in order to focus their efforts on the most influential ones. A global sensitivity analysis framework based on the open-source software NoiseModelling, which integrates the CNOSSOS regulatory method, has been developed and will be presented. An example of such an analysis, based on the Morris method, will be presented on a case study of a district in the city of Lorient, France.

1. INTRODUCTION

Strong relationships between noise levels and both annoyance and health effects are now established (1). It is therefore crucial to quantify the noise levels to which populations are exposed. Noise mapping is usual practice to quantify these exposure levels (2). Traffic and geometric data collected feed noise emission and propagation models to generate a map of noise levels over the city, which once crossed with the residential densities gives access to exposures.

It is important to use a stable methodology and modelling framework to compare the exposure levels of different cities, or the evolution over time of exposure to a given city. The Cnossos model has been proposed to participate in this harmonization of calculations (3). However, a large variability of the calculated exposures may remain due to the model configurations and to the type and accuracy of the input data. In addition, many input data are sometimes difficult to obtain or non-existent, requiring calculation assumptions that may influence the accuracy of the calculated exposure levels. It is therefore necessary to be able to understand the most important error elements, in order to give them priority in the data collection and modelling process.

This article presents the framework for a sensitivity analysis performed with the open-source Noisemodelling software (4). Regarding screening technique, the Morris

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method is applied, resulting in a high number of simulations combining different input parameter values, each parameter varying over a predefined range of variation. This paper is focused on the sensitivity analysis framework. During the oral presentation, results will be presented.

2. METHODOLOGY

2.1 Morris Method

The Morris method is widely used for global sensitivity analysis, since it is adapted to models with quantitative inputs (or factors) and outputs. It is part of the OAT (One At a Time) methods, meaning that the process of exploring the definition domain makes the factors vary one at a time. It can be seen as a statistical analysis of empirical estimates of changes in the output of the model with respect to each factor. In the case of a time-consuming model, or a model with a large number of factors (a few dozens), the method is a simple way to make a first selection among the factors according to their influence. It still requires an adequate number of repetitions to ensure the accuracy of the indices.

Its principle is as follows. The method starts by sampling a set of start values within the defined ranges of possible values for all input variables and calculating the subsequent model outcome. The second step changes the values for one variable (all other inputs remaining at their start values) and calculates the resulting change in model outcome compared to the first run. Next, the values for another variable are changed (the previous variable is kept at its changed value and all other ones kept at their start values) and the resulting change in model outcome compared to the second run is calculated. This goes on until all input variables are changed. This procedure is repeated r times, each time with a different set of start values, which leads to a number of $r(k + 1)$ runs, where k is the number of input variables. Such number is very efficient compared to more demanding methods for sensitivity analysis.

2.2 Framework

NoiseModelling (formerly NoiseM@ap) is as a free and open-source tool, integrated in the OrbisGIS software, designed to produce environmental noise maps on very large urban areas, with few computational resources. The CNOSSOS model is implemented for the estimation of road traffic emissions, as well as for the calculation of noise propagation. NoiseModelling allows information to be stored at three levels. The sources and their sound levels, the geometry of the propagation paths and finally the transfer matrix for each of the source/receptor pairs and for a given propagation path scheme. This choice was made because the computation time of software of this type is concentrated in the calculation of geometric rays. The calculation costs of the Cnossos model for emission and for propagation once the geometry is known and the rays are calculated, are considerably lower. To launch a large number of replications of the model, the idea is then to store the geometry of the rays and recalculate several possible emission levels for the sources, and several possible attenuations for the source/receptor couples according to the parameters to be varied. The jointing are then made between the source table Lw and the transfer matrices to calculate the noise levels results.

Figure 1 is a scheme presenting the framework more technically. A groovy script has been created to interact with Noise Modelling. It also serves as an interface with a database (PostgreSQL or H2). From a configuration file containing the variations on the

input parameters, many simulations are performed and the results are stored in compressed folders.
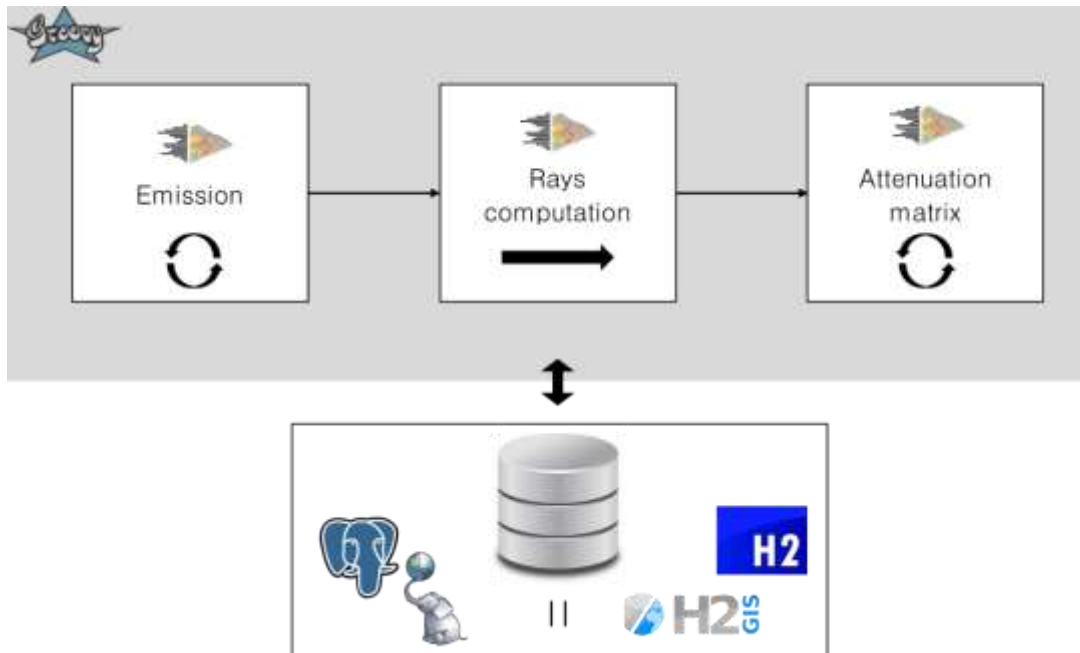

Figure 1 Sensitivy analysis framework using NoiseModelling

2.3 Study Area

The sensitivity analysis presented in this article is part of the CENSE project (Characterization of urban sound environments using a comprehensive approach combining open data, measurements and modeling), which includes a noise mapping case study based on both modelling and sensors deployment, in the city of Lorient, France (4). The noise map produced based on the modelling framework from the Directive 2002 serves as a support for the sensitivity analysis (see Figure 2). It covers an area of about 1 km².

Figure 2. Noise map of the study area computed with NoiseModeling

2.4 Study parameters

All the uncertain input parameters (emission or propagation) when creating a noise map will be variables in the sensitivity analysis. For example, it will be possible to observe the influence of a 10% variation in the hourly flow rate of light vehicles and compare it to a 5°C variation in temperature. It is also possible to complete the sensitivity analysis by varying the parameters related to geometry even if the calculation costs then increase - because the rays will have to be retraced - but without adding complexity to the process and analysis. As an output of the analysis, sensitivity to the model's input parameters will be observed on two quantities:

- The variation in the number of inhabitants exposed to a threshold level
- The deviation compare to a reference map produced with the best quality input parameters at our disposal.

4. CONCLUSIONS

This paper is a methodological presentation of the sensitivity analysis, the results of which are still being acquired and analysed. All developments of the NoiseModelling platform can be tracked on the open-source platform github[2]. The overall methodology was presented : It is based on the interaction between a GIS database (PostgreSQL or H2) and the open source software NoiseModelling, within the emission and propagation calculations have been splitted in order to optimize calculation times.

Thus, starting from a configuration file containing the variations on the input data (*i.e.* different values of influent parameters for noise emission, using Morris screening technique), many simulations can be carried out in order to perform the sensitivity analysis. It should be noticed that this methodology can be replicated by any user in any area, but also for other application as dynamic noise mapping, uncertainty propagation or to build a meta-model.

5. ACKNOWLEDGEMENTS

6. REFERENCES

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