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What precision in the Digital Terrain Model is required for noise mapping?

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ABSTRACT

The Digital Terrain Model is the most basic and cumbersome element of any large-scale mapping projects. Accurate assessment of Digital Terrain Model data is an intricate but vital process. The impact of its accuracy on noise mapping has not been fully researched. The aim of this research on a specific case study is to analyse the differences in noise mapping results obtained from acoustic simulations carried out with different accuracies in Digital Terrain Model data. It seems that mapping with a 0.5 m degree of accuracy in elevation is sufficient for acoustic simulation, apart from the fact that it is easily achievable with current available techniques. In contrast, it can be concluded that mapping with 5 m accuracy in elevation is insufficient and may drastically change the evaluation of the percentage of people affected by noise.

1. Introduction

A digital elevation model is a digital representation of the ground surface or terrain. It is also widely known as a Digital Terrain Model (DTM). It is generally represented as a raster, that is to say, a grid of squares. This 3D-representation of the land surface is basic information which must be collected prior to noise mapping. Features such as buildings, bridges, vegetation, etc. (as well as all data regarding noise sources) must be added to the DTM in order to evaluate the noise levels at any receiver point. Although DTM may be established by surveying the land it is commonly produced by using remote sensing techniques. A powerful technique for generating digital elevation models is interferometric synthetic aperture radar (either by two passes of a radar satellite or by a single pass if the satellite is equipped with two antennas) suffice to generate a digital elevation map with an approximately 5 m resolution. A more cutting-edge technique, known as LIDAR (LIght Detection and Ranging), uses optical remote sensing technology based on laser pulses instead of radio waves, which is the basis for conventional radar. By using the direct georeferencing GPS-Inertial technique a mapping accuracy of 10–15 cm in elevation is achieved [1].

In recent years thousands of acoustic maps of great agglomerations in Europe have been elaborated to fulfil the European Environmental Noise Directive, END [2]. A wide range of resolutions (either horizontal or vertical) have been used in the DTM. In fact, vertical resolutions from 0.5 m to 10 m can be found for various acoustic maps. For instance, two Digital Terrain Models (DGM5, DGM25) describing the terrain in regular grids with a 5 and 25 m dot pitch were applied in the acoustic map of Berlin and the neighbouring area of Brandenburg respectively [3]. Another example, regular grid with a 5 m dot pitch (vertical resolution of 0.5 m) was used in the latest acoustic map of Pamplona, Spain [4].

The European Commission Working Group Assessment of Exposure to Noise, WG-AEN [5], recommends that the ground elevation adjacent to the noise sources (e.g. roads, railway cuttings, railway embankments) may have to be provided within an accuracy of 1 m. For normal complexity (not quantitatively specified) in DTM and with reasonable cost, WG-AEN recommendations foresee high accuracy (<0.5 dB) in predictions. Nevertheless such predictions have not been firmly proven. A further problem arises in computer programs, especially when such a comprehensive file for the DTM is used, mainly for large areas of calculation. For a 5 × 5 m grid, 40,000 points per km^2 are used. For great cities (nearly 900 km^2 in the case of Berlin), the total number of points slows down or may even bring the process to a halt. In such cases, a simplification in the DTM is deemed necessary.

The most widely-used acoustic software can carry out a simplification of the grid points. This simplification may be appropriate to reduce computation time (e.g. for very small grids but in flat spaces). Simplification is often based on a criterion of tolerance. To set an example, if a tolerance of 1 m is applied, all interior grid points whose height differs by less than 1 m from all adjacent points will be removed. These removals certainly soften the ground. The reason for the differences in noise levels evaluated at each grid receiver from two different tolerances has without any doubt a thorough and rigorous explanation. It can be quantified following a propagation model adopted, such as ISO 9613-2 [6]. In general, it is due to the different screening which one or an-

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Table 1
Number of points in the DTM for each simulation.

Tolerance (m)	Number of points
0	196,292
0.2	16,777
0.5	6172
1	2559
2	1030
3	602
4	403
5	280

other tolerance implies. Nevertheless, it could also be due to the different discretization of the line sources because the software used carries out-prior to the discretization, an algorithm of visibility.

In principle using tolerances up to 0.5 m will not lead to significant changes in acoustic predictions. However, tolerances of 5 m or higher may seem to imply substantial changes due mainly to diffraction and screening effects. The aim of this study is to analyse the effects of this simplification in the DTM for a location covering both urban and rural areas.

2. Case study

The selected study area (5 km^2) is located within the agglomeration of the region of Pamplona (Spain). The DTM for this area is quite precise (5 × 5 m grid with vertical resolution <0.5 m). The study area includes a major road, a high-density intercity route, streets, residential and rural areas. Altimetry ranges from 399 m to 480 m. The resident population of the study area is 14,726 people. Cadastral information was also highly accurate. The number of residents per building and floor was available. A 10 × 10 m grid of receivers was placed 4 m above the ground. The number of grid receivers was 49,073. The calculation software utilised was CadnaA, v. 3.7 [7]. Simulations were performed with all input (road traffic noise computation method, traffic and terrain characteristics, etc.) and computational variables (search radius, reflection order, diffraction, etc.) being identical. The only difference in the simulations was set for the tolerance of the DTM grid. These tolerances were: 0, 0.2, 0.5, 1, 2, 3, 4 and 5 m. A command of the software package deletes the points whose heights deviate from each other less than the selected tolerance value. The result does not depend on the sequence of points when being entered or imported. In order to decide whether a height point has to be deleted or not,

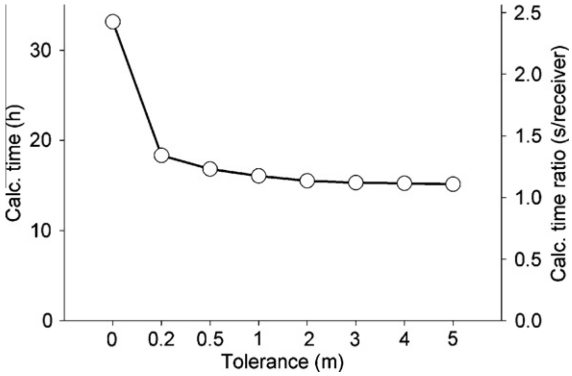

Fig. 2. Calculation time, in hours, and calculation time ratio, in seconds per receiver for the various tolerances.

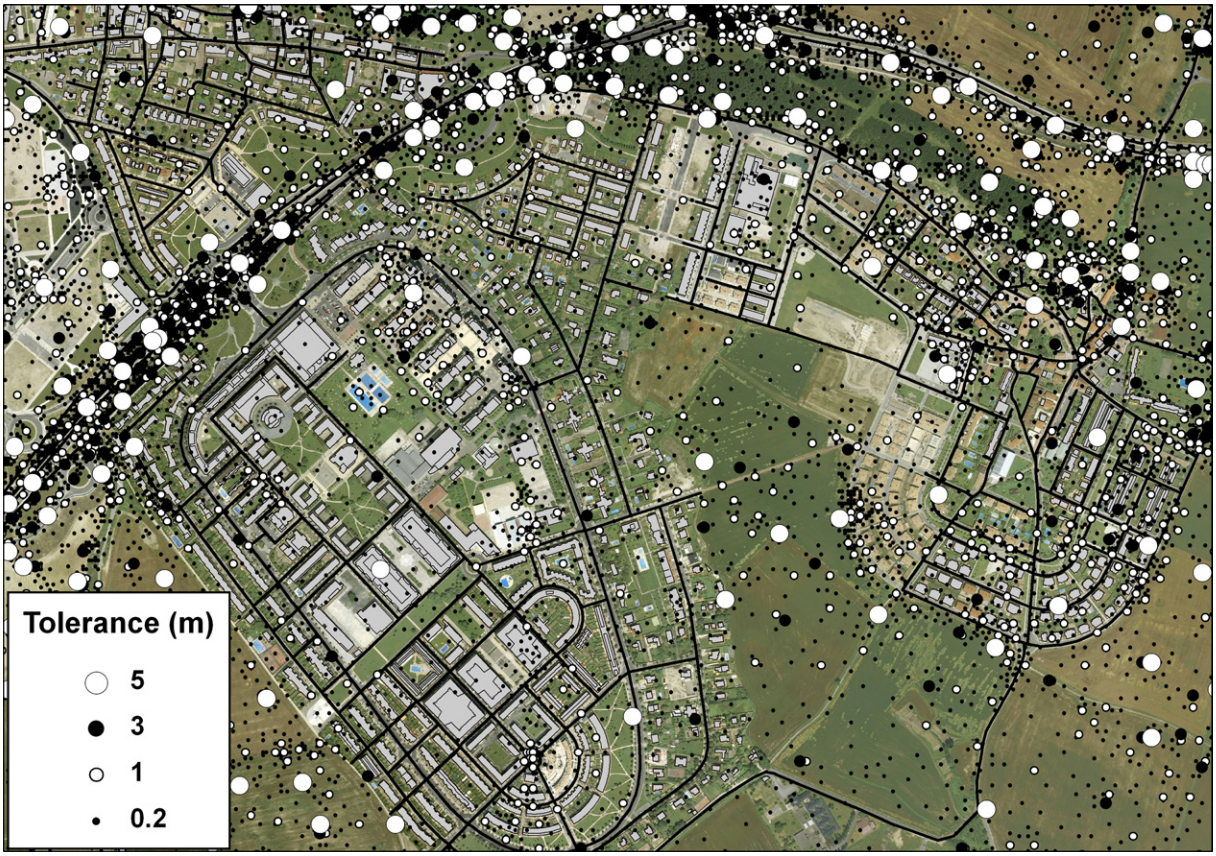

Fig. 1. Distribution of land points for 0.2, 1, 3 and 5-tolerance within the calculation area.