UNCERTAINTY IN NOISE MAPPING VERSUS PRECISION IN THE DIGITAL TERRAIN MODEL

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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.

Keywords: DTM, noise mapping, accuracy

1 Introduction

A Digital Elevation Model (widely known as a Digital Terrain Model, DTM) is a digital representation of the ground surface or terrain. In general, it is represented as a grid of squares. Prior to noise mapping work, such a 3D-representation of the land surface is basic information which must be collected. In order to evaluate the noise level at any receiver point many other features must be added to the DTM: data regarding noise sources, buildings, vegetation, etc. Although DTM was long ago established by surveying the land, the use of remote sensing techniques is now generalized. 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.
Currently, the prevalent accuracy of the LIDAR data is 0.5 m in position and 0.2 m in elevation. In recent years thousands of acoustic maps of great agglomerations in Europe have been elaborated to fulfill the European Environmental Noise Directive, END [1]. 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 describing the terrain in regular grids with a 5 and 25 m dot pitch were applied in the acoustic map of Berlin and the neighboring area of Brandenburg respectively. 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 [2]. The European Commission Working Group Assessment of Exposure to Noise, WG-AEN [3], 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. The aim of this study is to analyse the effects with regard to predicted noise levels of the accuracy in the DTM for a location covering both urban and rural areas.

2 Case study

The selected study area (5 km²) is located within the agglomeration of the region of Pamplona (Spain). The DTM for this area is quite precise (5 x 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 x 10 m grid of receivers was placed 4 m above the ground. The calculation software utilised was CadnaA, v. 3.7 [4]. 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 uncertainty of the DTM grid. These uncertainties were: 0, 0.2, 0.5, 1, 3 and 5 m. For this purpose, the original grid was considered as ‘exact’ and different random grids were created with the cited uncertainties.

3 Results and discussion

3.1 Noise level differences versus uncertainty

For all 49,073 grid receivers and uncertainties, level differences with respect to a 0-uncertainty have been calculated, obtaining maps such as that displayed in Figure 1 and Figure 2 corresponding to the highest and a medium uncertainty (1m) respectively. Figure 3 shows the distribution of the level differences for various uncertainties, yet again considering the ‘true’ value the one obtained with 0-uncertainty. Similarly, Figure 4 illustrates such a histogram on a cumulative basis (differences in absolute value).
Fig. 1 Map of differences in sound levels: 0 vs 5-uncertainty (absolute values).

Fig. 2 Map of differences in sound levels: 0 vs 1-uncertainty (absolute values).
Fig. 3 Level differences histogram *versus* uncertainty.

Fig. 4 Accumulated histogram of level differences (absolute values) *versus* uncertainty.

Using a 0.2-uncertainty in the DTM yielded results which were essentially identical. 100% of the points deviated less than 1 dB from the simulated 0-uncertainty.
As for the 0.5-uncertainty, 100% of the points sustained a deviation of less than 2 dB from the simulated 0-uncertainty and only 4.7% of receivers sustained a deviation which ranged from 1 to 2 dB.
The findings for a 1-uncertainty revealed a difference below 4 dB for the totality of the points with respect to the simulated 0-uncertainty whereas 49.4% of the points differed from 1 to 4 dB.
For a 3-uncertainty, 100% of the points varied less than 10 dB. In this case, the values of the points ranged from 1 to 3 dB grew up to 23.2% and 60.1% of the receivers varied from 3 to 6 dB.
Lastly, for a 5-uncertainty, the deviation produced was also less than 10 dB for the totality of the points although 9.3% deviated from 1 to 3 dB, 27.2% from 3 to 6 dB and 61.5% over 6 dB with respect to the simulated 0-uncertainty.
There is no widely-accepted criterion to determine whether predictions are accurate. Not even for a 0.2-uncertainty was the prediction by WG-AEN (Toolkit 11), which provides an error <0.5 dB, fulfilled in spite of the high cost and complexity to set up the DTM. However, only 0.22% of the points differed by 0.5 dB or more. Furthermore it can be concluded that the 5-uncertainty (accuracy of many DTM used in acoustic mapping so as to fulfil the END 2002/49/EC) is insufficient, because almost 98% of the values deviated by 1 dB or more. In section 3.2, the effect on the percentage of people affected will be analysed. As far as we are concerned, mapping with 0.5 m in vertical accuracy is sufficient for acoustic simulation, besides being easily achievable with current available techniques.
Due to the rapid progress cartography techniques are undergoing it is foreseeable that future acoustic maps of many agglomerations will be performed with a more precise DTM. Consequently it will be complicated to determine whether acoustic pollution will increase or decrease [5]. Similarly the effectiveness of any previously-designed measure in the actions plans will be questionable.

3.2 Influence on the percentage of people affected by noise

Determining the percentage of people exposed to environmental noise, through noise mapping, is one of the main aims for the END. A range of methodologies can be made use of to achieve this [6]. An assessment of the number of people affected by noise based on the criterion of the nearest grid point approximation is used in this research.
Comparing the percentages of people affected by noise according to various uncertainties is actually a troublesome issue. Positive differences can be balanced against negative differences. In order to evaluate the influence of DTM precision it would be appropriate to select previously a narrow range of values-above and below a limit value of a noise descriptor- and then carry out the comparison. A value of 65 dB for $L_d$ index was selected.
From the 0-uncertainty calculation (‘true’ calculation) Figure 5 displays all the façade receivers (all circles) whose value falls within the 64-66 dB range.
After 5-uncertainty evaluation, the findings vary. Some of the points where the ‘true’ value (0-uncertainty) did not exceed 65 dB, now do go beyond this limit (red circles). By contrast, others which were above this value are now not (blue circles). The conclusion drawn is that the percentage of people (within the range of 64-66 dB and evaluated with 5-uncertainty) has been modified by 44.6% compared to the ‘true’ calculation (0-uncertainty). Obviously, this variation is lower (5.5%) if the total number of people living in the calculation area is taken into account.

Figure 6 displays the comparison between the 1-uncertainty and “true” calculation.
In this case, the variation in the percentage of affected people decrease to 25.3% respect to the totally of points contained in the range of 64-66 dB and 3.1% if the total number of people living in this area is taken into account. Searching an explanation to this fact it was found great differences in DTM. Figures 7 and 8 represent the profile of the same cross section generated from both the 0-uncertainty and the 5-uncertainty calculation respectively. It is noticeable the roughness of DTM after applying a random uncertainty of 5 meters. Rough terrain works in some cases as a barrier shielding receivers from noise sources. This is the main reason why high sound level differences are found in the comparison carried out.
4 Conclusions

Different simulations have been performed by solely varying the accuracy parameter in the digital terrain model, DTM. With a vertical resolution of 0.2 m, the results are virtually identical to those obtained for a 0-uncertainty. From our viewpoint, mapping with 0.5 m in vertical accuracy is sufficient for acoustic simulation, besides the fact that it is easily achievable with current available techniques. It can also be concluded that the 5-uncertainty (accuracy of numerous DTM used in acoustic mapping in order to fulfil the END 2002/49/EC) is insufficient, as almost 98% of the values differed by 1 dB or more. Moreover, the evaluation of the percentage of people affected by noise may change drastically.

References


