Visualisation of traffic noise exposure and health impact in a 3D urban environment

Visualisation of traffic noise exposure and health impact in a 3D urban environment

Mikael Ögren[1], Jens Forssén[2], Patrik Höstmad[2], Beata Stahre Wästberg[2], Monica Billger[2], Vasilis Naserentin[2], Orfeas Eleftheriou[2], Fabio Latino[2]

[1] Sahlgrenska Academy, University of Gothenburg, Sweden (corresponding author)

[2] Chalmers University of Technology, Gothenburg, Sweden

Corresponding author's e-mail address: mikael.ogren@amm.gu.se

ABSTRACT

It is becoming increasingly common to work with urban planning using 3D visualisation tools. In the project DemoVirPEN a research team with participation from different research fields cooperated to create a demonstration concept for visualising traffic noise and the associated health impact in a 3D graphics environment. The project included participation from the following fields; 3D modelling and mapping, traffic noise calculation, auralisation, urban planning and architecture and health impact of noise exposure. The final product of the project is summarised in a film clip that illustrates the main results by visualising and auralising traffic in different configurations from different perspectives. A few key points are visualising short time frames (single vehicle passage) versus yearly average (noise map), and impact of changes such as removing or modifying traffic flows and buildings.

INTRODUCTION

When planning an urban area today it is common to analyse the traffic noise situation by using noise maps in a grid format for a single height above ground, or to use a few point calculations for different heights on facades. The traffic noise, or overall sound environment, is a key element in the environment of the planned area, but is often only included very late in the planning process. Also it is often a very black/white perspective, to see if noise levels at planned new buildings are above or below a certain limit. Health impacts of the noise exposure such as sleep disturbance, annoyance and cardiovascular disease [1] are not analysed or visualised, and no effort is made to auralise the soundscapes. In order to demonstrate a way that the sound environment could be included earlier in the urban planning process, and to integrate it more when developing plans, we developed and tested a demo-tool in the research project DemoVirPEN – *Demonstrator for virtual planning and scenario analysis of invisible environmental factors with focus on noise in the city*.

The prototype tool demonstrates how a city planner can move in a 3D environment with added visualisations and auralisations. In some cases the visualisation is static, for example when showing year-average equivalent noise levels, in other cases it is a dynamic visualisation of the sound level during a vehicle pass-by. The system also demonstrates how this can be used as an interactive tool, changing parameters such as vehicle speed, traffic flow or removing/adding buildings, and also giving statistics on other parameters that depend on the noise; such as number persons exposed above a certain value. The resulting visualisations and auralisations from the project are illustrated in a publicly available video [2].

PREDICTING NOISE LEVELS AND AURALISATION

In the beginning of the project a test area was selected based on 3D model availability among other parameters. It was also interesting to find an area where new buildings are planned, in order to see if the visualisation of the environment could aid in the urban planning of the area. The final area selected is illustrated in Figure 1, and is located in Johanneberg in Gothenburg.

Figure 1: Illustration of the 3D model of the selected study area with planned buildings shown in yellow.

For auralisation of vehicle passages and noise prediction in real time we used an approach in line with [3, 4], which yielded audio streams that then could be processed using head related transfer functions for binaural playback, or for stereo playback in simpler settings. For prediction of noise levels in the long run we used the Nordic method for road traffic noise [5] based on traffic flow measurements from Gothenburg municipality, and also predicted changes in the traffic flows by introducing the new buildings. For predicting changes in the noise level when introducing electric vehicles we utilized measurements from the FOREVER EU-project converted for use with the Nordic method [6].

RESULTS

Figure 2 shows the final version of the proposed visualisation/auralisation tool's interface, where real time noise is illustrated using transparent surfaces coloured according to noise level, and where listener/viewer can move around and be presented with binaural sound and the corresponding visualisation. The listener/viewer can also interact with the scenario by changing parameters such as vehicle speed, vehicle type (electric/combustion) or building parameters, here illustrated with the information area to the right.

Figure 2: Illustration of the visualisation/auralisation tool in use with dynamic real-time noise levels illustrated with transparent coloured surfaces.

Another part of the tool can be used to visualise long term average noise levels in the form of equivalent free field noise levels at the building façades. A general problem when trying to show information as false colour in 3D environments is that light and shadow necessary for a better spatial understanding influences the colour and makes precise extraction of information via colours in such plots difficult. This is similar to how colour may interfere with spatial depth perception on 2D maps using hill shading [7]. For illustrations of the equivalent noise level on building façades this is problematic if several shades of similar colours carries information, for example if red is one level and a darker red is another, and parts of a building coloured red on the façade is in shadow, giving a darker red. The problem is reduced if fewer steps are used in the colour scale.

During the project four workshops with students were performed to test different noise visualisation strategies and colour scales. The evaluation of the workshops showed that different versions of the often used rainbow colour scale (green-yellow-red-purple) were less easy to understand than simpler sequential scales for example from light green to dark red [8].

DISCUSSION

The DemoVirPen project showed a possible tool for urban planning that auralises and visualises the noise situation. It also discussed a few central details regarding the use of appropriate colours and which visualisation strategies are most appropriate. Showing noise levels as false colour in 3D environments is challenging, but also very informative and useful for future urban planning tools.

Using auralisation in parallel with real-time colour on transparent surfaces gives an intuitive understanding and is very useful for those not very familiar with acoustics and traffic noise. For noise experts the plots of equivalent levels are more appropriate, and gives more detailed information. Interacting with the environment is a key component what will form a better understanding, for example changing the speed of the vehicles and get immediate feedback both visually and aurally. This is useful for both experts and others. As an example it would be illustrative to show the predicted number of a certain health outcome as a bar chart or as numbers; and then observe how this changes when removing or adding traffic. Health outcome in this case could be as simple as the predicted number of annoyed or sleep disturbed residents, or as complex as the number of excess cases of hypertension per year due to noise exposure.

Perhaps a seamless transition from real time visualisation to equivalent noise levels could be an important tool for explaining what the noise map actually represents; this was suggested by one of the students during the workshops. This could perhaps be visualised as single vehicle passages splashing paint/colour on the façades and streets, and after many passages the virtual paint would form a stationary situation which corresponds to the final noise map.

ACKNOWLEDGEMENTS

The work was funded mainly by Chalmers Area of Advance Transport. It is also part of the Digital Twin Cities Centre supported by Sweden's Innovation Agency Vinnova under Grant No. 2019-00041.

REFERENCES

[1] WHO, Environmental Noise Guidelines for the European Region. 2018: Copenhagen.

[2] DemoVirPen. DemoVirPen: Virtual planning and scenario analysis of noise in the city. 2020 [cited 2021]; Available from: https://youtu.be/-4btcZW-g1c.

[3] Forssén, J., A. Hoffmann, and W. Kropp, Auralization model for the perceptual evaluation of tyre–road noise. Applied Acoustics, 2018. **132**: p. 232-240.

[4] Nilsson, M.E., et al., Perceptual validation of auralized road traffic noise, in 40th International Congress and Exposition on Noise Control Engineering, Osaka,Japan,September 4-7, 2011. 2011, Institute of Noise Control Engineering/Japan & Acoustical Society of Japan: Tokyo, Japan. p. 3453-3460.

[5] Kragh, J., et al., Road Traffic Noise - the Nordic Prediction Method. 1996, Nordic Council of Ministers: Copenhagen.

[6] Ögren, M., P. Molnar, and L. Barregard, Road traffic noise abatement scenarios in Gothenburg 2015 - 2035. Environ Res, 2018. **164**: p. 516-521.

[7] Çöltekin, A. and J. Biland, Comparing the terrain reversal effect in satellite images and in shaded relief maps: an examination of the effects of color and texture on 3D shape perception from shading. International Journal of Digital Earth, 2019. **12**(4): p. 442-459.

[8] Forssén, J., et al., An urban planning tool demonstrator with auralisation and visualisation of the sound environment, in Forum Acusticum. 2020, European Acoustics Assosiation: On-line.