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(article starts on next page)

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AN URBAN PLANNING TOOL DEMONSTRATOR WITH AURALISATION AND VISUALISATION OF THE SOUND ENVIRONMENT

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ABSTRACT

The paper presents findings from a recent project about the development of a demonstrator of an urban planning tool that includes auralised sounds as well as visualisations of both sound propagation and façade noise levels linked to health impact. In urban development projects, the sound environment is one of the key elements, but often enters late in the planning process. As a result, even if the noise regulations are fulfilled, the potentially good sound environment may suffer from unnecessary quality defects. In addition, the standard ways of presenting and analysing the situations, using noise levels and noise maps, have potential for improvement, especially when considering the transdisciplinary approaches to planning that are increasing in use. This tool aims to simplify the usage also at early stage planning, including scenario analysis, as well as to facilitate urban planners' understanding of the sound environment and its effects. The paper presents results from the development of the prototype, reflecting on auralisation as well as on multiple aspects of visualisation including grid noise maps, health-related façade noise levels and choice of colour scales.

1. INTRODUCTION

Today's urban planning uses calculated grid maps and façade levels of noise pollution, whose constrained and abstract information content limits the usage. It would be beneficial to have an improved planning tool, which through visualization and auralization (sound simulation) can provide better understanding of the impact of various factors in sustainable urban development. Challenges in visualization include how to display several types of parameters at the same time, how to use symbolism and photorealism in the same urban model, and what colour scales to use. A prototype of such a tool for virtual planning and scenario analysis has been developed 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 the user can move in a visual and auditory 3D environment with added visualization of selected factors like time-dynamic grid noise maps and stationary yearly-average noise levels, which are linked to legislation and health effects. Target groups are decision makers and other users in urban planning as well as citizens in general.

2. NOISE LEVEL PREDICTION AND AURALIZATION

The calculations of the auralization and the time-dynamic grid noise maps are based on detailed outdoor sound propagation modelling. The approach follows the methodology described in [1,2] with the additions that first-order diffracted paths are included (using the Harmonoise model [3]) and that the amplification in energy due to first-order façade reflections is reduced in strength following the Fresnel zone approach (as detailed in the work of the Nord2000 modelling [4]). Also, the façade reflections are given a reflection loss of 1 dB. The diffraction and the reflections in ground and façades are modelled in third-octave frequency bands. Hence the spectral behaviour of sound propagation above and around obstacles is captured. Other parts of the auralization is made in time-domain at high sampling frequency (44.1 kHz). At the receiver, a binaural response is calculated using head related transfer functions (e.g. [2]), assuming the direction of arrival of the sound being from the vehicle to the receiver. The yearly average noise levels are calculated based on Swedish standard (e.g. [5]).

3. DEVELOPMENT OF COLOUR SCALES AND VISUALIZATION

3.1 Elaborations with Noise Level Colour Scales

Regarding the readability of a visualization, one challenge lies in how to combine map material and abstract colouring of environmental data. The importance of applicable colour selections is pointed out by e.g. Borland & Taylor [6], who refers to the challenges connected to the popular rainbow scale (see Figure 1).

Figure 1. Example of a rainbow scale.

Rainbow scales are usually based on a few colours from the colour circle, meaning that the order of the colours is difficult to intuitively or perceptually interpret, compared to for example a palette ranging from a dark colour to a lighter one. The rainbow palette has been criticized for not being as effective as other colour palettes in communicating information [7,6]. When colours in a rainbow scale which are not perceptually ordered are used to visualize ordered data, confusion can arise. A rainbow scale can furthermore obscure data through not being able to show small details. Also important to take into consideration when it comes to the target audience, are cultural or natural connotations of specific colours. [8]

In our elaborations with colour scales, several examples of two types of scales were developed: (1) scales with colours ranging in two directions (diverging scale), and (2) scales with a more limited scope of colours (sequential scale), see Figure 2.

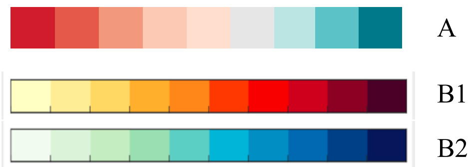

Figure 2. Examples of two types of scales. *Diverging scales* (A) are developed for situations when we want to show limit values. For this, two contrasting colours are used. *Sequential scales* (B1 and B2) are developed for showing values that range from low to high noise levels (in dB) without adding any assessment. For this, more monochrome scales can work, e.g. a scale that ranges from weaker to stronger or from a lighter to a darker colour.

In this project, we have used colour scales from ColorBrewer (https://colorbrewer2.org/) as a starting point for elaborations. However, due to the 3D contexts, transparency was added to the scales, which changes their appearance. Because of this the colour scales needed modification to visually work in the 3D model, where they are influenced by the background. The context is highly influential on how a scale is perceived in 3D, e.g., if the model's colour scheme is muted or more monochrome, a more chromatic scale can be used, whereas if the model is more chromatic, the scale may need the use of patterns or similar.

The prototype with different colour scales was tested and evaluated in four workshops with students from Chalmers University of Technology, University of Gothenburg and YRGO (higher vocational education in Gothenburg). How visual aspects are experienced, e.g. preferences for colour maps and differences between how colour is perceived in 2D and 3D, were investigated and discussed. Various concepts for visualizing noise were also evaluated, including painting of building façades to display yearly average noise levels as well as horizontal and vertical planes with colour scales representing the sound levels in the vicinity of the noise sources, i.e. the vehicles, as exemplified in Figure 3.

Updating of the prototype was made with input from the workshops. Participants confirmed that it was difficult to interpret the rainbow scale, both in 2D and 3D. The best working colour scale in a 3D visualization according to the participants, which we ultimately chose to use in the project, is shown in Figure 3.

Figure 3. Visualization of noise in the project with a colour scale ranging from lighter yellow to darker red, where red symbolizes the strongest noise area and yellow the weakest.

3.2 3D Visualization

The output of the simulations was visualized in the Digital Twin Cities Platform [9], the open source e-infrastructure of the newly founded Digital Twin Cities Centre [9], a national competence centre hosted by Chalmers University of Technology. In summary, the platform is a toolset that enables the visualization and interaction of urban-related research in Unreal Engine [10] in an automated and spatially accurate manner. For the current project some new features were developed in order to enable the vertex painting of the building façades, accommodate the custom made colourmaps and time-marching of procedural meshes. Moreover, considerable non-automated effort was carried out in the urban design of the selected area inside the platform, with the aim of creating an immersive and pedagogical user experience that provides enough information about the current state of the district in focus, as well as integrates the planned changes. Priority was given to elements that can convey human scale and place-based identity. Besides adding 3D models of pedestrians and cars, specific street furniture, such as the local benches, were included. Of equal importance is to replicate the style of the existing façades; openings such as windows and doors were replicated in the virtual model to resonate with the real-world example. High polygons geometries were preferred over photorealistic textures.

To our knowledge there is limited, if any, open source usage of Unreal Engine for creating this kind of multidisciplinary urban planning application that strives to fuse existing topological characteristics, multi-physics simulation with planned large-scale urban developments and the resulting health impacts.

3.3 The Case Study Area

For our case study, we chose an area with planned residential buildings and a medium trafficked road (Gibraltarvallen, Göteborg, Sweden). The area was of interest as it will be subject to urban densification. New high-rise buildings will replace an existing parking lot situated alongside almost the full length of the road; this change will interact with the sound environment as the street canyon will change dramatically. In our case study we also took into consideration the addition of a wider sidewalk and of greenery to separate the two lanes of traffic.

4. CONCLUSION

A prototype of an urban planning tool was created. The tool aims to simplify planning, also at early stages and including scenario analysis, and help the urban planners increase their knowledge about urban sound environment and its effects. Unreal Engine is used as a basis to create this multidisciplinary tool, which to our knowledge is a novel open source usage of the engine. Developed new features include enabling of building façade vertex painting, accommodating the custom made colourmaps and time-marching of procedural meshes.

Results from the development of the demonstrator has been presented, including aspects of auralization and multiple properties of visualisation considering grid noise maps and representation of health-related façade noise levels. In particular, improved colour scales for 3D models are suggested. Participants in user tests confirmed that it was difficult to interpret the traditional rainbow scale, both in 2D and 3D. A semi-transparent sequential scale ranging from yellow to red turned out to work best in a 3D visualization according to participants. A video demonstrating the prototype tool was also made [11].

In future work it is of interest to continue the development primarily in the automation of model build-up, calculation of environmental parameters, and their visualization and auralization. A natural next step in the process would be to conduct user reviews of the final development tool, both in expert and citizen groups, in order to evaluate the overall design and implementation. For the auralization, future work could focus on a further spatialization of the sound as received by the listener.

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