Title	Audio noise mapping in virtual urban simulations : enhancing public awareness
Author(s)	Murphy, Enda; Rice, Henry J.; Pilla, Francesco
Publication Date	2007-08
Publisher	Turkish Acoustical Association
This item's record/more information	http://hdl.handle.net/10197/3001

INTER-NOISE 2007

28-31 AUGUST 2007
ISTANBUL, TURKEY

Audio noise mapping for virtual urban simulations: enhancing public awareness

Enda Murphy[a] and Henry Rice[b]
Dept. of Mechanical & Manufacturing Engineering
School of Engineering
Trinity College Dublin
Dublin 2
Ireland

ABSTRACT

One of the key difficulties with urban environmental noise mapping is disseminating results from noise studies in a manner that is easily understood by the general public. Indeed, it is one of the requirements of the Environmental Noise Directive (END) that information from noise studies is disseminated to the general public so that awareness of environmental noise issues is increased. This paper presents preliminary work undertaken to integrate results from environmental noise studies into a virtual sound environment. The model uses appropriate sound mixing techniques to integrate background sound from prediction software while direct sound is integrated from appropriate sound samples. In the virtual environment sound is output using audio rendering and clustering techniques which take account of the position of the individual in the virtual environment. The model demonstrates the possibility of using virtual urban simulations as a framework for evaluating the environmental and visual impact of major urban developments particularly in terms of the impact on the surrounding urban soundscape. In addition, the model framework may be used as a demonstration method whereby the sensitivity of the urban sound environment to different traffic management scenarios is presented to urban inhabitants.

1   INTRODUCTION

There is increasing concern in European countries about the impact of noise pollution on individual health and quality of life. It is an ongoing problem and one which the European Union (EU) has attempted to address through the recent European Noise Directive [1]. Apart from noise mapping major agglomerations, roads, railways and airports in EU states the Directive requires that local authorities compile noise action plans for areas mapped; it also requires that information from noise studies is disseminated to the public in a manner that is 'clear, comprehensible and accessible' [1, P.16]. The later requirement highlights the emphasis which the EU places on increasing awareness about noise pollution and its scope throughout individuals States.

The main focus of this paper is to outline the process of (1) integrating environmental noise mapping information into a virtual environment (VE) and (2) to document the role that can be played by virtual audio noise mapping both in terms of increasing public awareness of environmental noise but also as a tool for aiding environmental planning in urban areas.

---

[a]   Email address: murphyen@tcd.ie
[b]   Email address: hrice@tcd.ie

2   VIRTUAL ENVIRONMENTS AND ENHANCED ENVIRONMENTAL AWARENESS

In recent years there have been rapid user-end developments in modelling virtual environments (VEs). These technological advancements are rapidly being introduced to aid in the urban planning process as well as to simulate the outcome of a specific process or development [2, 3]. Within the field of urban planning and design, virtual models are seen as a means of aiding the decision making process through the enhanced visualisation of development proposals and building design. They are also viewed as a way of increasing public participation in the urban planning process by demonstrating, in a realistic fashion, the aesthetic influence of proposed developments on the surrounding environment. Crucially from the viewpoint of this paper, virtual models can potentially play an important and effectual role in the dissemination of various forms of urban and environmental planning information in a manner that is both intuitive and easy for the general public to understand [4, 3]. This is particularly important due to the increasing emphasis being placed on effective communication of urban environmental planning information to the general public.

One area in particular where virtual models have the potential to offer a valuable contribution, both in terms of more informed decision making and the dissemination of information to the public, is in the area of Environmental Impact Assessments (EIAs). In Ireland, major development proposals require an environmental impact assessment (EIA) to be carried out together with an environmental impact statement (EIS) when submitting planning applications (Dept of Environment, 1989). EIA is a process for examining the existing environment and evaluates the potential impact on humans, flora and fauna, soils, water, air, climate (including noise), the landscape, material assets and cultural heritage resulting from a proposed development. It is a means of identifying the environmental impacts that are considered to be unacceptable from a proposed development so that they can avoided or at least reduced during the planning and design stage [5]. The virtual Dublin model will allow for a range of urban ad environmental planning considerations to be assessed in a highly realistic manner prior to developments being initiated.

From the viewpoint of this paper, the role of virtual models in disseminating realistic noise mapping information to the general public is of particular importance. Accordingly, the audio noise mapping process will now be outlined together with a conceptual schematic of the audio noise mapping process.

3   AUDIO NOISE MAPPING

3.1   The Current Noise Mapping Process

In the EU, the current noise mapping process involves a number of specific steps before the compilation of noise maps and associated action plans for public viewing (Figure 1). One of the key difficulties with urban environmental noise mapping is disseminating results from noise studies in a manner that is easily understood by the general public. Results from noise studies are generally displayed in strategic 2D noise maps with some maps offering 3D representations of 2D information [6]. An added difficulty with current noise maps is that they noise levels are displayed in decibels (dB(A)) which are not intuitive for on-specialists. The decibel scale is a log scale whereby noise intensity roughly doubles with every 10 dB(A) increase in noise and this is a concept which is extremely difficult to convey to the general public via traditional noise maps.

An added difficulty is that the perceived relationship between a noise level of (say) 70 dB(A) and the actual sound is that an individual will hear on the street is unclear for the vast majority of people. Therefore, providing a means of linking the numerical output from noise studies with realistic sound information is highly desirable, particularly as a means of disseminating information to the general public in a more intuitive manner. This research

proposes a potential solution to the foregoing issues by integrating strategic noise mapping information with realistic sound information in a virtual audio environment.

3.2   The Potential Role for Audio Noise Mapping

Figure 1 shows the noise mapping process as it currently exists and also shows the potential for realistic sound information to be incorporated into the noise mapping process. As can be seen, there is potential for realistic audio information to be integrated into the noise mapping process. The audio information is incorporated in to the virtual environment after the noise map is constructed. It has the potential to be used both to disseminate environmental noise information and also as a method for engaging in collaborative feedback from the general public which can then be used to inform noise action planning.
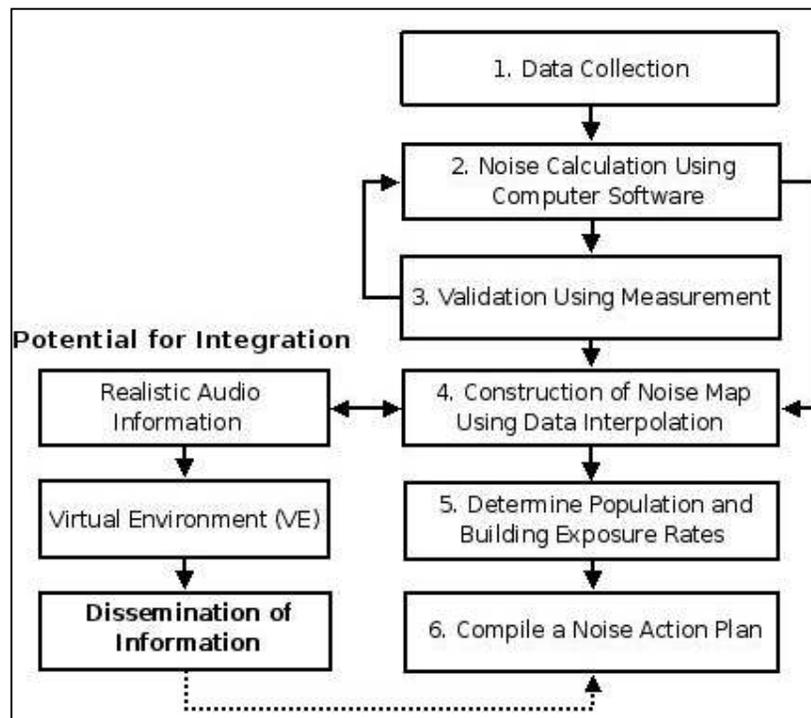

Figure 1. The Noise Mapping Process

4   PREVIOUS WORK

To date there has been no previous work completed on integrating the results of noise mapping studies with realistic sound information in a virtual 3D environment. However, there has been a considerable amount of work done on 3D audio rendering for complex virtual scenes, with particular reference to application in the computer games industry. This approach is particularly relevant to audio rendering of direct sound sources in real-time in an interactive virtual environment. While this level of realism may not be necessary initially for environmental noise mapping purposes it undoubtedly enhances the level of realism and interactivity in the virtual sound environment and may be used to for   increasing awareness of other forms of environmental noise.

In a novel piece of research related to this area, Tsingos *et al* [7] proposed the use of a novel method of rendering spatialised audio in complex virtual scenes. They produced new algorithms based on perceptual culling and a sound source clustering strategy which allowed rendering of a large number of sound sources. The first stage in their approach applies perceptual masking to cull unimportant sound sources; it then clusters sources using

perceptual criteria before leveraging graphics hardware to accelerate audio processing operations. The results produced showed that the approach is highly successful at dealing will a large number of sound sources in real-time VEs. More recently, Tsingos [8] and Moeck *et al* [9] and have presented significant speed improvements of the clustering approach advanced in Tsingos *et al* [7] by introducing a new recursive clustering method and this method has been adopted in the commercial games environment.

5   METROPOLIS: VIRTUAL AUDIO NOISE MAPPING FOR DUBLIN

5.1   Metropolis and Virtual Dublin

Metropolis is an interdisciplinary project combining computer graphics, engineering and cognitive neuroscience to create a realistic, scalable and large-scale simulation of Dublin. As a basis for the research, the project uses a virtual Dublin model with accurate building geometry and texture as well as realistic street scenes, crowds and sound incorporated into the environment. Human multi-sensory perception techniques are used to validate the realism of the virtual environment and particularly the sound environment.
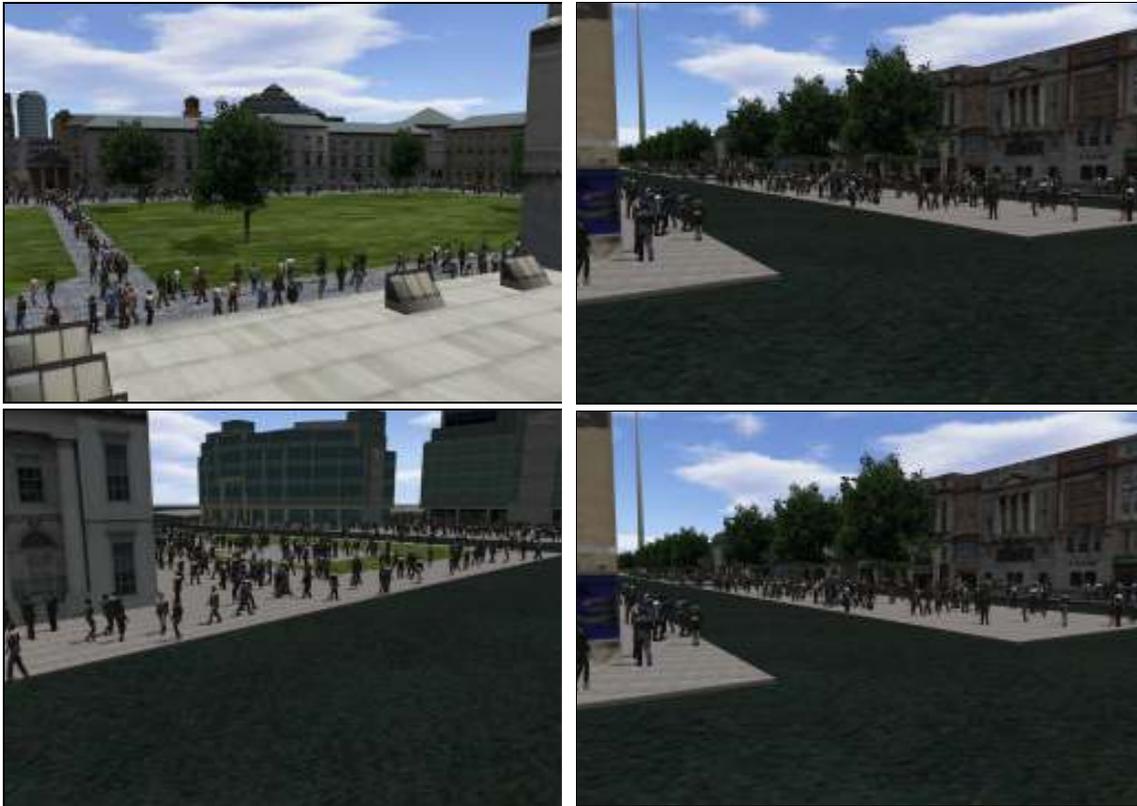

Figure 2. Virtual Dublin Model

A core objective of the Metropolis project is to simulate realistic traffic noise in a virtual environment and validate the level of realism achieved with principles of human multi-sensory perception. A crucial issue from a noise mapping viewpoint is that ambient traffic noise is modelled in noise prediction software prior to being incorporated into the virtual environment thus offering high level of realism.

The noise mapping is achieved using traditional noise mapping procedures producing results which are then incorporated into the virtual environment. This approach provides a unique level of realism to the traffic simulated in virtual urban models not only because it takes account of sound source considerations such as daily traffic volumes but also the fact

that the methodology takes account of attenuation and propagation factors such as building geometry, ground topology, meteorological factors as well as road surface considerations.

5.2   The Audio Noise Mapping Process

Figure 2 shows a schematic of the phases involved in the audio noise mapping process. The first phase involves what is essentially the prevailing noise mapping procedure in EU states (see Figure 1) whereby noise maps are compiled in accordance with the criteria laid down in the European Noise Directive (END) [1]. The current project proposes the introduction of an additional noise mapping phase – the audio noise mapping phase - to create a more realistic and interactive noise environment.
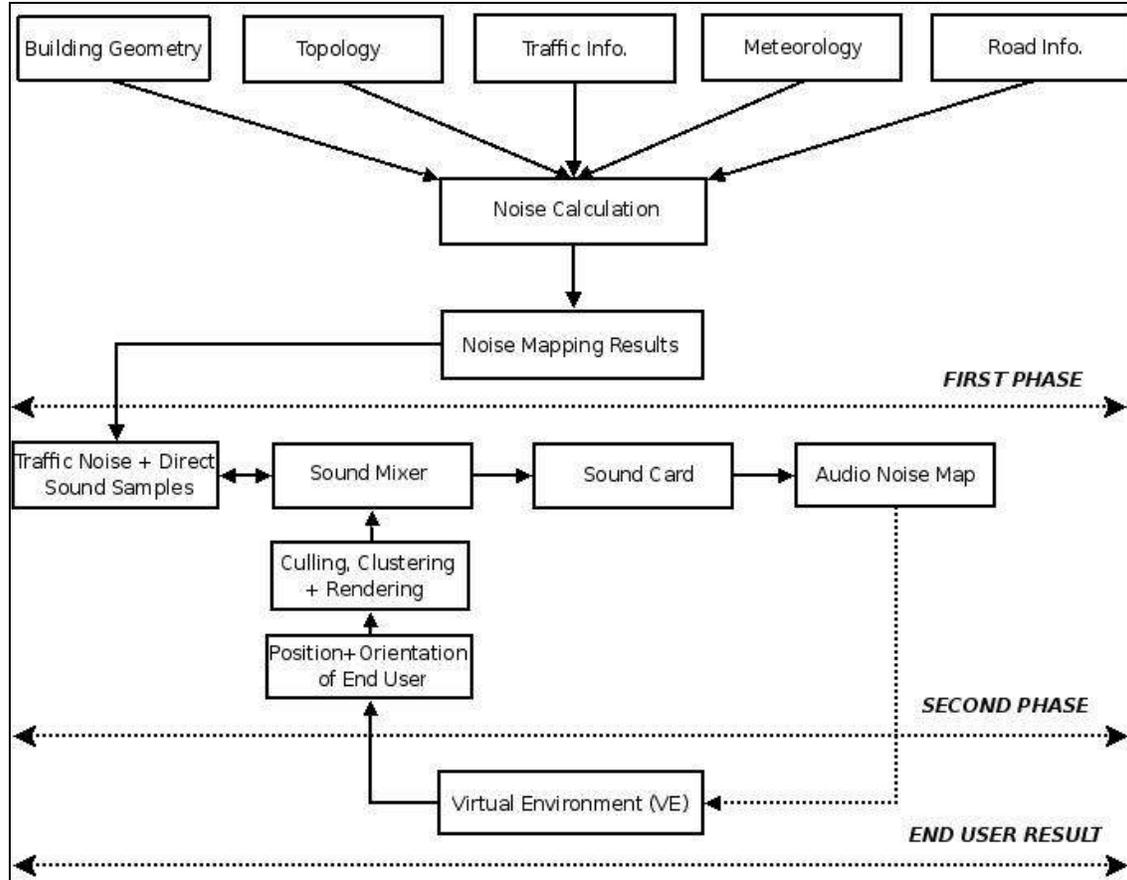

Figure 2. Schematic of the Audio Noise Mapping Process

The audio noise mapping process involves collecting a range of stereo sound samples corresponding to the noise mapping results (dB(A) produced for the study area. Appropriate stereo samples are selected for the virtual model which is linked to a sound mixing file. Depending on the co-ordinate position and angle of orientation of the end user (which is read at 0.5 second intervals by the sound mixer file driving the sound card), a audio output is produced using appropriate weighting of the pre-selected sound tracks based on the decibel value produced at the co-ordinate location of the end user[1].

Direct sound is modelled as individual sound sources using spatial clustering techniques for 3D sound sources similar to those described in the literature [7, 8, 9]. The advantage of

---

[1]This value is derived from the noise calculations undertaken during the noise mapping process. The values at coordinate locations are then integrated into the virtual Dublin environment.

spatial clustering techniques is that inaudible sources can be eliminated dynamically while the remaining audible sources are merged into reduced number of clusters. Each cluster is represented by one impostor sound source and is positioned using perceptual criteria. This means that spatial audio processing is performed only on the impostor sound sources rather than on each individual original source which greatly reduces the computational load required for rendering [7, 8, 9].

6   A MODEL FRAMEWORK FOR ENHANCING PUBLIC AWARENESS

There is little doubt that realistic sound information derived from the noise mapping process would significantly enhance in the dissemination of noise information to the general public. Furthermore, the use of such a tool would be invaluable in compiling noise action plans particularly in situations where a number of noise abatement modelling scenarios are to be assessed. For example, virtual noise mapping could be used to assess, in a highly realistic manner, the noise impacts of individual traffic management strategies that may be proposed in noise action plans. This would simply involve integrating the results from revised noise modelling calculations (where traffic is restricted along particular links) into the virtual environment with appropriate sound mixing strategies. The model could also be used to realistically assess the potential attenuation and propagation effects as well as the visual impact of noise barriers on surrounding environments. On a broader scale the model could also be used in an urban planning context to assess the suitability of both small ad large scale development projects on the local environment [10]. In this context, the current research could be used as an assessment tool in Environmental Impact Assessment (EIA) for both small and large scale development proposals.

7   CONCLUSIONS

This paper has demonstrated the potential role that can be played by audio noise mapping in the wider noise mapping process. In particular it has shown that audio noise mapping has significant potential to be used as a vehicle for disseminating results from noise mapping studies conducted under the European Noise Directive. It has potential also to be used as a method for engaging in collaborative noise action planning, particularly where local communities are involved. A conceptual schematic of the audio noise mapping process has been presented and the process of modelling ambient and direct noise has been outlined. Future research will concentrate on the more sophisticated directionality in terms of modelling moving 3D sound sources as well as applying psychoacoustic principles to validate levels of realism of sound and traffic noise in the virtual environment. This should provide insights as to the factors that are important (and the level of detail needed) for recreating an accurate audio representation of street in virtual urban simulations.

REFERENCES

[1]   Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002, *Official Journal of the European Communities*, L189, 12-25.

[2]   Rangizer, M. and Gleixner, G. (1997) GIS datasets for 3D urban planning, in Hodgson et al (Eds.) *Proceedings of 3rd JEC*-EGI, Vienna, 298-307, Netherlands: 105 Press.

[3]   Dodge, M., Doyle, S., Smith, A. and Fleetwood, S. (1998) '*Towards the Virtual City: VR & Internet GIS for Urban Planning*', Centre for Advanced Spatial Analysis (CASA), University College London, May 1998.

[4] Dodge, M., Smith, S. and Doyle, S. (1997) '*Visualising urban environments for planning ad urban design*', AGOCG Graphics, Visualisation and the Social Sciences Workshop (Report No. 33)

[5] CASS Ltd (2002) '*Draft Guidelines on the Information to be contained in Environmental Impact Statements*', Ireland: Environmental Protection Agency (EPA).

[6] Murphy, E., Rice, H.J., and Meskell, C. (2006) 'Environmental Noise Prediction, Noise Mapping and GIS Integration: the case of Inner Dublin, Ireland', *Proceedings of the 8th International Transport Noise and Vibration Conference*. St. Petersburg: East-European Acoustical Association.

[7] Tsingos, N., Gallo, E., Drettakis, G. (2003) '*Perceptual audio rendering of complex virtual environments*', INRIA, Rapport de recherché n.4734, February 2003.

[8] Tsingos, N., (2005) 'Scalable perceptual mixing and filtering of audio signals using an augmented spectral representation', *Proceedings of the 8th International Conference on Digital Audio Effects*, Madrid, Sept, 2005.

[9] Moeck, T., Bonneel, N., Tsingos, N. Viaud-Delmon, I., Alloza, D. (2007) 'Progressive Perceptual Audio Rendering of Complex Scenes', Proceedings of i3D Symposium on Interactive 3D Graphics and Games, Seattle, WA, April 30th -May 2nd.

[10] Drettakis, K., Roussou, M., Reche, A., Tsingos, N. (2007, *forthcoming*) 'Design and Evaluation of a Real-World Virtual Environment for Architecture and Urban Planning', *Presence: Teleoperators and Virtual Environments*, MIT Press.