Börner, Katy, Fehr, Rainer, and Wachsmuth, Ipke. (1998). AkuVis: Interactive visualization of acoustic data. *Computer Science for Environmental Protection'98: Networked Structures in Information Technology, the Environment and Business*, Haasis, H. D. and Ranze, K. C. (Eds.), Metropolis Verlag, Volume 1, pp. 722-728.

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AkuVis: Interactive Visualization of Acoustic Data

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Abstract

AkuVis (Interactive Visualization of Acoustic Data) is a joint project involving the Artificial Intelligence as well as the Visualization Laboratory at the University of Bielefeld, government researchers from the Institute of Public Health NRW and the Local Environmental Agency Bielefeld as well as the German TÜV (Börner 1997). The project seeks to create a highly interactive virtual environment of modelled acoustic data in order to sensitize and improve human decision-making in real world tasks. In particular, it attempts to enhance the integrated understanding of noise data as a basis for governmental decisions about noise protection regulations for new streets, industrial areas etc.

1. Motivation

Environmental noise or "community noise", i.e. all noise exposure outside the industrial work place, is a well-known risk factor (Jansen & Notbohm 1994). Suspected and proven negative implications for human health are numerous (cf. below). In many areas, emissions from road traffic are the major source of environmental noise pollution. Actual levels of noise exposure depend on a variety of factors, including traffic density as well as spatial distance between sources and receptors. In spite of accumulated knowledge on negative health effects, it is often difficult to implement noise abatement measures. Environmental noise is seen as one of the major environmental health problems still awaiting a satisfying solution.

The organization of the paper is as follows. The current section starts out by motivating the need for new interfaces to comprehend and manipulate complex data. Section 2 contains an overview of noise-related issues from an Environmental Health perspective. Section 3 introduces the visualization of environmental noise pollution data in terms of an 'acoustic landscape'. Section 4 explains the general setting used for human-computer interaction. The paper concludes with an outlook.

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2. Noise and Environmental Health

Major sources of environmental noise include the following (Berglund & Lindvall 1995, p.16ff.):

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- Industrial plants, machinery, ventilation systems
- Transportation systems: road, rail, and air traffic, incl. impulse events such as sonic booms
- Construction and public works, incl. garbage disposal and street cleaning activities
- Building services noise, incl. ventilation, air conditioning, lifts etc.
- Domestic or neighborhood noise, incl. lawn mowers, TV sets, and hobby activities
- Noise from leisure activities, e.g. motorracing, water skiing, and shooting.

Community noise is a genuine environmental health problem. At 65 dBA sound pressure level, sleeping becomes seriously disturbed and most people become annoyed. Almost 25% of the European population is exposed, in one way or another, to transportation noise over 65 dBA. In some countries, more than half of the population is exposed to this level (Berglund & Lindvall 1995, p.1). "Taking all exposure to transportation noise together about half of the EU citizens are estimated to live in zones which do not ensure acoustic comfort to residents" (p.19).

The effects of noise exposure depend not only on the sound pressure levels but also on the type of noise, and on the number of noise events. Up to now, there is no general model that relates physical measures of sound to auditory experiences (e.g., loudness) and, in turn, to annoyance of community noises (Berglund & Lindvall 1995, p.50). The complex interrelationship of traffic noise, sleep, stress, and health is being investigated in several scientific studies (cf. Maschke, Ising & Hecht 1997 for a recent review). It is important to note that even without awakening effects, there is a chance of significant changes concerning, e.g., the sleep structure and stress-related endocrine functions.

In summary, for an evaluation of noise exposures from a Public Health perspective, the following effects of noise on humans should be taken into account:

- Noise-induced hearing loss, incl. temporary and permanent threshold shift, with effects of impulsive noise awaiting more detailed investigation
- Sensory effects, incl. aural pain, tinnitus, and paracusis
- Interference with speech communication, with particular relevance for people with hearing deficits / dysfunctions
- Sleep disturbance effects, incl. effects on time to fall asleep, awakening effects, psychophysiological reactions (on heart rate, respiration rate), changes in sleep

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stage distribution, after-effects of noise-disturbed sleep (fatigue, changes in mood, impairment of performance)

- Psychophysiological effects, stress responses, and cardiovascular effects; the overall evidence is suggestive of a weak to moderate effect of community noise on blood pressure
- Mental health effects
- Performance effects
- Effects on residential behavior (e.g., aggression) and community annoyance (Berglund & Lindvall 1995, p.29ff.).

A key instrument for prevention of noise-induced health impairment are "R-ecommended guideline values". Such guideline values need to be differentiated according to physical setting, social activities, day of time, and vulnerability of population. Therefore, there are different recommendations for dwellings, outdoor living areas, outdoor play grounds, schools and preschools, espec. during teaching sessions. Hearing impaired children may require still lower levels than what is needed for school settings in general. Since patients have less ability to cope with stress, special guideline values are needed for hospitals and all other rooms in which patients are being treated, observed, or resting (Berglund & Lindvall 1995).

3. Interactive Visualization

Noise exposure is an everyday experience, but the exact relationship between determinant factors and exposure levels is not always obvious. A better understanding of noise exposures should be helpful for an adequate assessment of the local situation, especially for the selection of noise abatement measures. Therefore, this project aims to provide decision-makers and the public at large with a very vivid demonstration of local noise levels, using acoustical as well as visual information.

The virtual environment created by the AkuVis project can clarify crucial interrelations concerning noise emission, ambient noise levels, human exposures, and health effects. In addition, the AkuVis environment can demonstrate the impact of a variety of distinct measures ranging from traffic mitigation to road resurfacing. "What-if" demonstrations can be applied to city noise abatement programs as well as transportation planning and traffic flow management. The visualization and interactivity features are expected to be useful for planners, decision-makers, and the interested public.

A well established method of visualizing data of environmental noise pollution are 2D plots. However, decision makers are often uncomfortable with the conventions used and the complexity inherent in these plots. In AkuVis, acoustic data are mapped into a 3D visual and acoustic space that provides a much higher

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"bandwith" and can be explored interactively. Noise pollution data modelled by the German TÜV are mapped onto the three dimensions (x/y for position, z for dB level) of an "acoustic landscape".

Figure 1: Acoustic landscape and interaction elements

Visually, users experience a richly detailed, interactively changeable landscape illustrating the noise conditions in a city district of Bielefeld. The landscape is rendered in real time as high-resolution stereoscopic images for a tracked user. Acoustically, the landscape can be explored by way of a "virtual ear", i.e. a virtual sensor in the shape of a human ear. The "ear", as shown in the middle of the landscape in Figure 1, is controlled by a tracking device. It can be moved across the "acoustic landscape" and lifted up in the z dimension. Its position determines the sound level, frequency, and kind of sound samples played to provide an acoustic impression of the noise conditions in the modelled city environment.

Figure 1 depicts a view on the acoustic landscape at night as well as the interaction elements. The buttons on the right hand side allow for the selection of either the *Title*, i.e. information about the project name and project partners, the *Houses* view presenting the houses and streets only, and the *Night* and *Day* view projecting the dB values for night and day conditions in terms of an "acoustic landscape" respectively.

Additionally, the user is free to activate (check-mark):

- *Label*, inserting the street names,
- *Sound*, turning the street noise on,
- *Tracking*, replacing active head tracking by a standard normal view,[1]

or

[1] This option is especially helpful if the required frame update rate of 30 Hz can not be achieved due to the limited computing power of the SGI machine used.

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- *Sensor*, inserting the "ear", as a kind of virtual sensor for acoustical exploration, in the landscape.

In such a way, user actions are instantly reflected in 3D graphics and stereo sound.

4 Setting

Figure 2 shows the general setting used for human-computer interaction in AkuVis. Position sensors - one at the side of a pair of shutter glasses and one on the back of a stylus-glove respectively - keep track of the users eye and hand positions. One user acts as an active viewer, controlling the stereo projection reference point. The other users are passive viewers. Instead of using a mouse or keys the user handles this environment by manipulating virtual objects.

Figure2: General setting used for human-computer interaction

The *Responsive Workbench* (Krüger & Fröhlich 1994), developed by the German National Research Center for Information Technology (GMD), is used as output device. It allows to fuse a real workbench - used as projection plane for the acoustic landscape - and virtual objects, i.e., the landscape itself as well as interaction elements, i.e., the ear, buttons, and check-boxes. Users, wearing LCD shutter glasses, can take advantage of 3D vision in a field of about 170cm x 120cm size.

Additionally, the acoustic landscape may be projected on a larger screen of about 250cm x 250cm size, named *Wall*, allowing to reach a larger audience but for the cost of interaction. Sound samples are played via a stereo audio system.

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5. Outlook

In a next step, the project aims to implement more detailed noise modelling, allowing, e.g., for the demonstration of different noise abatement scenarios. Using appropriate dispersion models, the approach can be extended to include chemical emissions and resulting exposures. It will be interesting to gather evidence if this type of visualization does indeed improve the understanding of exposures and abatement measures for the sake of environmental protection and human health promotion.

Geographic Information Systems (GISs) are used to collect, process, analyze, and present multidimensional data about our world. The Responive Workbench may prove to be a valuable interface to create simpler, more effective, human-computer interaction with todays GIS systems.

Concerning noise abatement policies, the German federal government holds that, in most cases, it is necessary to combine technical, planning, administrative, and educational strategies. Federal noise abatement policies are based on the following principles: Noise abatement at the source, espec. by further development of noise abatement technologies; primacy of noise-reducing planning over amendments implemented in later stages; use of market mechanisms; continued development of international and national regulations; education and information on noise-reducing behavior, directed at decision-makers and the public at large (BMU 1996, p.79).

In summary, the main options of noise exposure and effect control are (Berglund & Lindvall 1995, Appendix I):

- Engineering control, incl. physical planning, source replacement and modification, path modification
- Administrative means, incl. environmental guidelines, occupant and consumers equipment modifications, work place organization

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Other means, incl. hearing protection devices, educational and information programs.
There is reason to assume that the educational and information programs mentioned in both sources can profit considerably from an attractive, interactive information environment as pursued by the AkuVis project.
In current licensing and authorization procedures, vast amounts of technical information are involved. Typically, all or most of the information is still paper-bound, resulting in very voluminous sets of documentation files. It has been claimed that these application materials and often also the subsequent expert evaluations of the material result in excessive demands for everybody involved in the procedure. The amount, complexity, and technicality of the information involved is said to prevent a real understanding of alternatives and their implications. It is claimed that

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multi-media information technology should be helpful in providing all interested parties wih a better understanding of the issues at stake. In this reasoning, it is important to supplement the "modeling laboratory" with a separate "validation laboratory" (Roßnagel 1997).
Perhaps the AkuVis environment can contribute to the modeling and validation laboratories that may assist planners, decision-makers, and the public to reach consensus and viable decisions on future development projects.

Acknowledgements

We would like to thank GMD's Digital Media Lab for furnishing our Lab with the Responsive Workbench. The authors are grateful to Heiko Rommel and Timo Thomas who did substantial work on the implementation of the system. Additionally, we thank Elke Bernauer and Wolfgang Goldbeck for providing data material as well as Peter Serocka and Marc Latoschik for giving technical advice.
The research is partially supported by the Institute of Public Health NRW.

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