Noise Abatement Planning - Using Animated Maps and Sound to Visualise Traffic Flows and Noise Pollution

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Abstract

As noise becomes more and more important as an environmental threat to human well-being, a growing amount of measures against noise have to be taken. Maps have been essential to communicate the spatial dissemination of noise for planning purposes since the beginning of the last century. But static paper maps lack the possibility to communicate the complex four-dimensional phenomenon of noise in an understandable way. In this article new visualization techniques such as dynamic display and acoustic rendering of the qualitative and quantitative dimensions of noise are presented. It is argued that both experts and novices involved in the urban planning process can profit from multimedia noise maps in a way that may lead to better decisions about which measures against noise will be taken.

Introduction

There is world wide a growing concern about the quality of our living environment, which has remarkably deteriorated in the last thirty years. Main expressions of this concern are related to climate change, air and water pollution and subsequent defoliation and drought. Noise is another polluting agent which may affect human well being and which is receiving increasing attention in the press and political arena. Contrary to other global polluting factors, noise is a local nuisance which concentrates in urban areas. Urban areas are everywhere increasing, however, which means that an increasing number of people are or will be affected by noise hazards, whether they come from road and air traffic, industrial, commercial or recreational activities. Predictions are that the urban population will double until 2025 to reach then 4,6 billion people (Meurer, 1997). There is thus a sense of political urgency to control and limit the growth of noise in urban agglomerations, since political pressure to undertake something against noise is increasing in all major cities. In Europe, for example, most of citizen complaints registered in the last five years and related to the environment are about noise. (European Commission, 1999). Measures against noise from city governments can already be observed in multiple ways, such as creating green buffer zones around hospitals and elderly people residences or imposing speed limits along highways crossing residential areas.

Planning measures against noise require several types of knowledge including noise sources, noise intensity and type, and the spatial propagation/distribution of noise patterns. A typical planning exercise in the struggle against noise is to look at residential areas and identify the critical points where noise intensity may be considered intolerable and hazardous for human health. This information is then used to propose a series of protection measures which are both economically and humanly acceptable. This information may come in form of numerical listing or written reports, but it is obvious that the most efficient way to convey such information is in a map form. This is not surprising, since noise, like temperature or rainfall, is typically a spatially distributed phenomenon. In fact, the use of maps to convey information about noise is nothing new and has existed for some time (Fig.1).

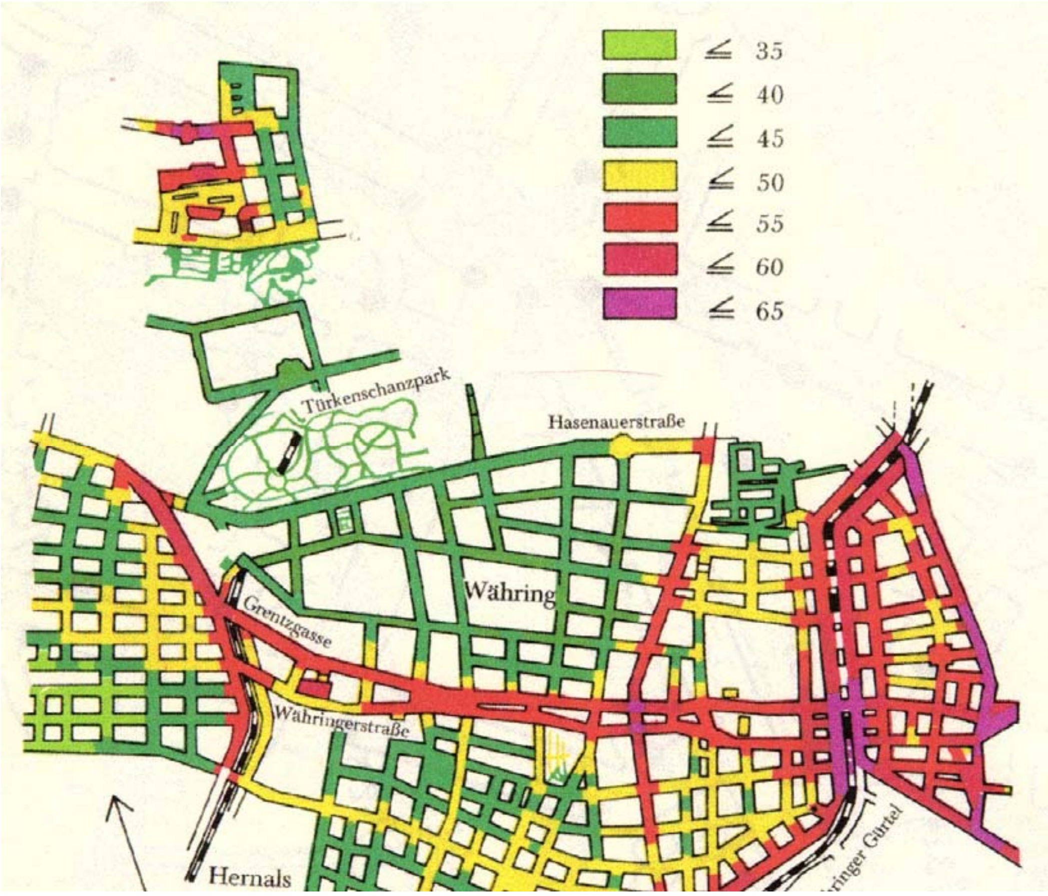

Figure 1. Noise map of Wien (1967/1968) (Glück, 1973)

The objective of this paper is to show how maps may be advantageously used to analyse and communicate noise information, using the newest available technology based on multimedia and computers. We investigate new methods of representation and scientific visualisation, with the objective of improving the tools available for planning purposes and policies aiming at noise reduction. This paper builds upon a previous paper presented at the latest ICA conference in Ottawa, in which we already discussed some methods of cartographic representation (Müller et al., 1999). First we will recall some of the latest development in various visualisation techniques involving the use of multimedia and acoustic cartography. Then we will discuss the availability and form of noise data, looking at the various aspects of noise information which need to be analysed and visualised, including the quantitative, qualitative, temporal and psychological dimensions of sound. Finally, we propose specific solutions to the communication of noise information, and discuss their potential validity for planning and political decision making.

Latest Developments in Visualisation Techniques

Four paradigm shifts have characterised the evolution of cartography in the last four decades (Fig. 2):

1) The first paradigm shift, which roughly began at the end of the fifties, was the automation of paper map production. National mapping agencies and resource related industries were the driving forces of such a shift. Their motivation was to produce traditional analogue products, such as topographic and cadastral maps, more efficiently than ever before, by driving down the costs and time of production.
2) The second shift occurs with the realisation that digital technology could be used not only to produce traditional maps automatically, but to create new map products which did not appear in the market before. Examples of these new types of maps are non-paper maps (sometimes called virtual maps, see Moellering, 1979) produced only on the screen of a monitor for analysis and temporary purposes. New visualisation techniques were then made possible, such as continuous hill shading, online multiple scaling, three-dimensional animated viewing, computer cartographic movies and classless categorical maps.
3) The third paradigm shift is related to the so-called "democratisation of cartography", which began in the eighties, with the appearance of private computers, desktop mapping software and societal needs to take advantage of the new unlimited access to spatial information. In Morrison's words, democratisation here

means that "all individuals are potentially empowered with the available electronic tools to think geographically and to make visualisations of their thinking" (Morrison, 1997). In this sense the general public is not only the user, but the producer of multiple single maps which are free from traditional standards such as scale, conventional symbols and accuracy.

4) The fourth and last paradigm shift which occurs in the nineties was prompted by a convergence between the multimedia revolution and internet. Whereas multimedia added a new dimensionality to the cartographic language, internet provided the necessary platform for the general public to become familiarised with the use of multimedia cartography. Multimedia applications include the use of animation, interactive hyperlinks and sound. In fact, this later period of the cartographic evolution was made possible through the convergence of the three last paradigm shifts, namely a) virtual maps as a window to spatial databases, b) democratisation of map making oriented towards private needs, and c) multimedia interactivity for unstructured search and display of spatial information.

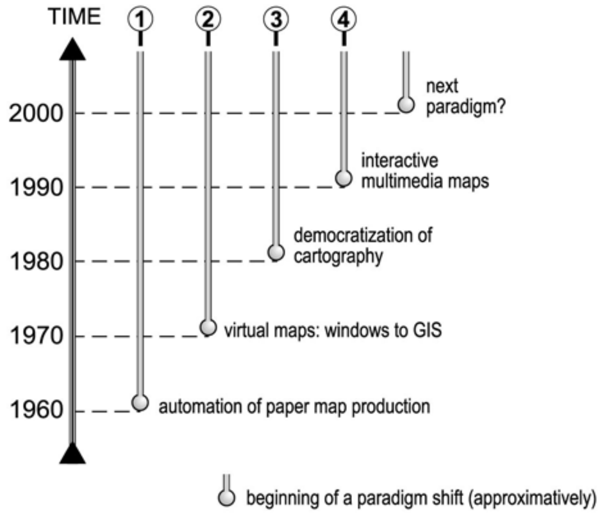

Figure 2. The four cartographic paradigm shifts

Multimedia Maps: The Acoustic Dimension

The fourth and last paradigm shift mentioned above shall be excellently illustrated in our project which aims at communicating noise information. Our proposed solution requires a combination of dynamic interactive visual display and sound. Sound is of course an ideal medium to convey noise information, since there is a perfect adequacy between the phenomenon to be represented and the tool used for its communication. Whereas there is a strong historical and theoretical foundation for producing visual displays in cartography, based on graphic variables and layout rules which can be found in any textbook, sound is a relatively new comer in contemporary cartography and its potential usage is still largely untapped. Sound applications in multimedia cartography have been for the most part limited to the use of popular or classical music as a companion to make a visual presentation more attractive, or the use of speech to add explanation to a picture without overloading the screen with written text. But there are very few examples of the acoustic dimension being used as an extension to the visual variables introduced by Bertin more than thirty years ago (Bertin, 1967). One interesting application of sound can be found in the communication of meta-information, such as data quality and uncertainty in GIS, where an alarm or a strident tone is prompted to notify the user that her/his cursor is entering a zone of unreliable information (Fisher, 1994; Krygier, 1994; Van der Wel et al., 1994).

One of the difficulties of course is that sound alone cannot communicate spatial relations in two or three dimensions. Acoustic signals are meant to be heard, not seen, and they operate on a total different basis than the signals conveyed by an image (Fig.3). They are transmitted through a one dimensional channel of communication, whereas an image communicates in two or three dimensions. They can be meaningfully interpreted only if heard sequentially, whereas our vision is parallel, which means that an image is not seen according to any particular sequence or path. Time and sound duration dictate and control the human perception of sound. On the contrary, time is not a direct constraint in the observation of an image (the observer determines her/his own time of viewing). Bertin (1967) made previously the distinction between maps to be read and maps to be seen, arguing that a criterion for good cartographic design is that a map should be seen, not read. Can we make good quality maps to be heard? We intend in this paper to demonstrate that sound can indeed be effectively used for geographic visualisation but with one condition: hearing for cartographic communication can only be conceived as an addition, not a substitute to pictorial vision. Sound is not a cartographic variable (like colour) in the classical sense. Like interactivity, sound may help to enhance the representational repertoire of cartography based on visual variables. In our case study, sound will be used to emulate noise on top of a geographically referenced document which could be an air photo, a land use map or a satellite picture.

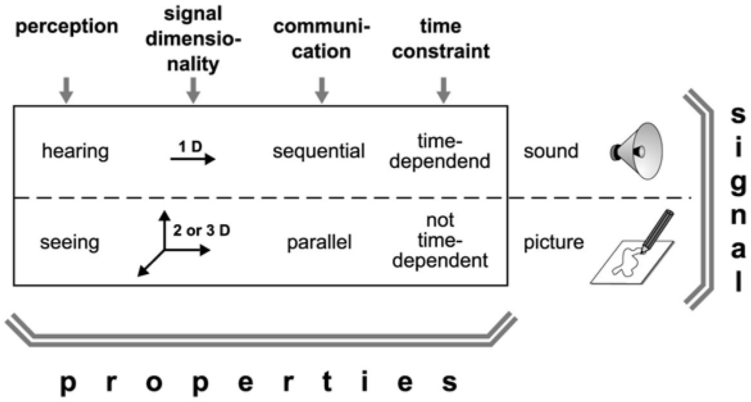

Figure 3. Property differences between hearing and seeing.

Urban Noise Information: Problems of Data Capture, Measurement and Interpretation

Before discussing the problems of data capture, measurement and interpretation we need to differentiate between sound and noise.

What is sound and what is noise

Sound is a complex notion which may be physically analysed according to physical variables such as location, loudness, frequency, duration, rate of change and the like (Krygier, 1994). For sake of clarity, one may refer sound to its spatial dimension (location), its quantitative dimension (loudness), its qualitative dimension (frequency or pitch), and its temporal dimension (duration and rate of change). Noise is a polluting agent affecting human well being and is usually perceived as a combination of unwanted or undesirable sounds characterised by their spatial, quantitative, qualitative and temporal dimensions. Each of those dimensions are spatially distributed, which means that theoretically one could try to map all of those, and produce a variety of maps or layers, one for loudness, one for pitch, one for duration and rate of change or a combination thereof. This leads to the notion of noise landscape (Schafer, 1977 ;Servigné et al.,1999).

Sound produced in urban areas is typically negatively perceived as noise. This occurs for obvious reasons: the sound landscape of a city is predominantly a noise landscape since most of what we can hear is noise produced by street, railways and air traffic. But some city sounds may be more agreeable to hear, such as the bell of a church, human conversations in open restaurants or shopping centres activities. Hence we need to go beyond the mere notion of noise when collecting data about the acoustic of a city. Instead we should try to characterise the environment from a psychological point of view, combining annoying noise and stimulating sounds. An attempt has been made to capture the auditory entities of streets in the city of Nantes (France), which led to the notion of acoustic urban environment (“ambiance sonore urbaine”) whose spectral signature varies from place to place (Leobon, 2000).

The psychological aspect of urban sound is certainly an important issue but requires further research which goes beyond the scope of this paper. Instead, we concentrate mostly (but not exclusively) on the spatial, quantitative aspects of urban noise. Loudness measured in decibels and location (where does the noise come from and where does it go) are the first aspects to be considered in communal planning and political circles which are responsible for noise abatement. Recommendations and regulations about noise emissions and propagation at the national or European levels also only refer almost exclusively to the spatial and quantitative aspects of noise. Hence we will consider the problems of data capture only under those aspects.

Data Capture and Measurement

The first laws against noise have been passed in the 17th centrury and since then measurement techniques have been improved depending on the available technology. Until the end of the 19th century loundness could not be measured because the adequate devices had not yet been developed. For that reason certain sounds were forbidden at certain locations as e.g. singing or shouting in the streets on feast days (city of Bern, Switzerland, 1628) or noise in the vicitnity of churches (city of Bern, Switzerland. 1788) (Schafer, 1977). Although noise had

been recognized for many centuries the first mesurements date back to the early 20th century. One of the first noise maps was developed by the city of Berlin in 1938 (Glück 1973). Since then noise has been defined mostly on a quantitative basis.
In the late 1960th and early 1970th a considerable amount of cities in Germany developed noise maps based on comprehensive mesurements. The measurement locations, sometimes several hundred, have been distributed across the city as evenly as possible and several measurements were made during a defined time period to obtain data with a high resolution in time and space. After that noise maps were derived through data interpolation or simply by drawing the values on a map. Mainly three different cartographic methods were applied depending on the available technology

- point symbols, colour (e.g. Berlin 1968/69)
- shaded line symbols, b/w, color (e.g. Berlin 1938)
- shaded choropleth maps, b/w, color (e.g. Berlin 1959)

These comprehensive examinations have turned out to be very expensive due to the personal involved and the amount of used measurement devices. And as the budgets of local authorities decreased in the 1980th less and less cities could afford setting up a noise cadastre for the whole municipal area.
A change occurred in the 1990th when computers became faster and software for noise modelling was developed. From then onwards noise was not measured directly anymore but simulated on the basis of several parameters as the amount of traffic, street surface, street slope, allowed driving speed etc. An important advantage of this development is that not only the existing noise of today can be simulated but also the noise of tomorrow by simply changing the parameters. E.g. if a city plans a new bypass road the effect on the noise in the city center can be computed based on the expected traffic reduction.
In our project we have used simulated noise data for an area of the city of Westerland/Sylt in Germany. The simulation was carried out by an engineering office with the noise modelling software “Soundplan” and subsequently converted to a dxf-file format.

Visualisation of Urban Noise: Graphic Depiction and Multimedia Presentation

The purpose of our research is to exploit the latest developments in visualisation techniques to find new forms of communicating noise information. Those new forms should be accurate enough to satisfy the information needs of the expert in charge of planning decision but also practical enough for the layman or the politician to understand. Hence the visualisation techniques must be largely flexible to satisfy different needs.

In our last ICA paper we reported on traditional mapping techniques and presented new ones (Müller et al. 1999). The traditional techniques, which are still today much used in governmental planning agencies, are discrete, graphical, multicoloured representations showing the intensity of noise along streets and highways, as well as in the surrounding neighbour settlements. Three dimensional representations are also used to show the variation of noise spreading with various intensities on building faces (Direction Régionale de l’Equipement, 2000). The new techniques we suggested were continuous, multimedia representations showing the propagation and intensity of noise at every location. We used a combination of graphical variables (like colour), as well as sound and hyperlinks to simulate the intensity of noise and query a database (pictures at a given location, numerical tables, etc.). We have now extended those new techniques, improving some representation capabilities and introducing new ones.

Full Size Screen with Zoom In and Out Functions

Any (x,y) location (pixel) takes on a scalar value defined by a noise function f(x,y). This function is single value and has a range from 0 to 255. It is computed from discrete noise values which are themselves derived from traffic information. The noise data field f(x,y) was computed using the TIN program from ArcView. The multimedia representation with a continuous rollover function prompting the sound of noise for every location (by either mouse click at discrete points or by moving the mouse continuously over space) was programmed and realised using Lingo, a programming extension of Director.
The new added facility offers now the possibility of creating a full size screen representation, without having to parse enormous amount of data, since the new version of Director (Director 8.0) offers the posibility to read out color values of raster images. Theses color values are subsequently converted to sound levels. The zooming function was programmed using Lingo as well, because the size of the zoomed image has to correspond with the original size to get the correct sound at every position.

Transparent Layer Function

Noise propagation may be better understood if associated with other spatially distributed phenomena such as land use, transportation, vegetation etc. Measures for noise abatement are obviously meant at protecting the citizens against noise pollution. Hence it is necessary to put in relation the spatial distribution of noise intensity with the spatial distribution of people. To do so one requires the capability of overlaying different geographical layers, such as noise, cadastre, aerial photographs, vegetation etc. This overlay operation is a typical GIS function. In this project we have developed an interactive visualisation technique showing the relationship between two layers (noise map and aerial photograph) which are being overlaid. One layer is made partially transparent, which gives the possibility to look at both layers simultaneously. The user can tune the degree of transparency for each individual layer interactively, in order to optimize the viewing.

Dynamic Display and Acoustic Rendering of the Qualitative Dimension of Noise

We mentioned previously that noise pollution is usually a combination of different types of noise coming from different sources such as cars, railways, air traffic, industry, recreational activities etc. Although noise intensity measured in decibels is currently the single criterion being used for deciding on protective measures against noise pollution, there may be a difference in the way people react when exposed to different types of noise, some being more or less intolerable than others. Moreover not all sounds of the urban environment are considered in the traditional noise abatement planning. A park e.g. produces different sounds (singing birds) that will not be called noise but nevertheless exist in reality and are part of the urban soundscape. Sounds can be negative in quantity but positive in quality and there is no reason to generally omit positive sounds.

New techniques were accordingly developed to communicate both the quantitative and qualitative dimensions of noise. Using a rollover function, one can use the mouse to scan an aerial photograph continuously along multiple locations. A noise map could not be used as spatial reference in this case, because auditory information about several sounds are presented simultaneously. The spatial location and movement of the sound sources (e.g. traffic flows) are shown by animated symbols. Two communication events are then taking place: 1) one can hear a sound which is a mixture of different types of noise, each type being weighted according to its intensity, the intensity of the global volume of sound being of course the sum of the intensities of the individual noise types, and 2) one can observe the intensity of the individual types of noise by looking at a bar graph acting as some sort of spectral display. Each individual bar of the bar graph represents one type of noise (i.e. car, train, park etc.). The bars move dynamically up and down according to the intensity of contributing noise types (Fig. 4). In this way up to eight different sounds can be combined according to the eight sound channels which can be played simultaneously by using Lingo.

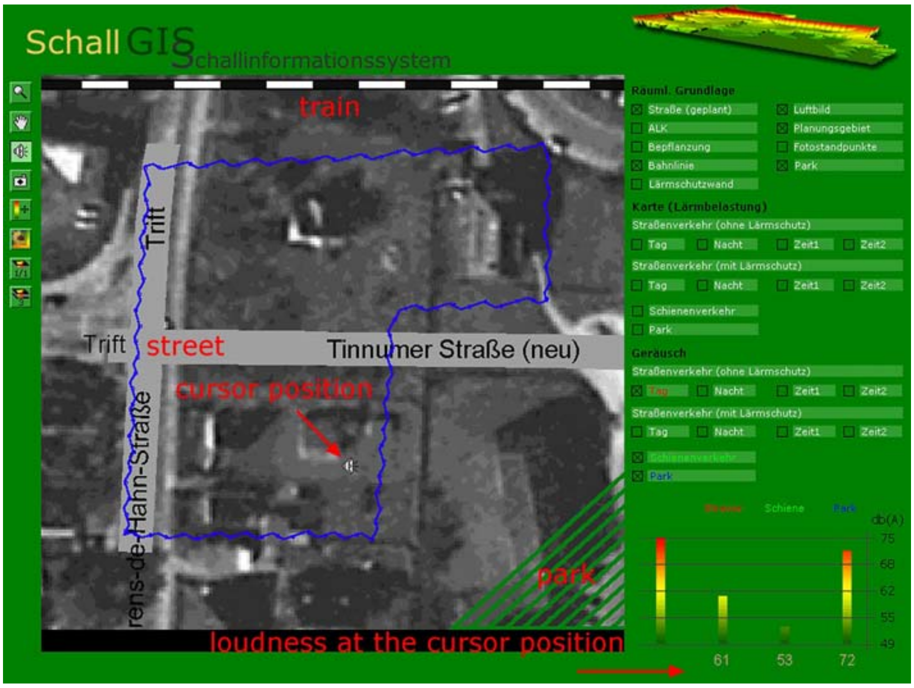

Figure 4. Combining different sounds at every cursor position.

Moveable Legend Function

An effective understanding of the geographical distribution of noise cannot be achieved by hearing sound alone. One needs a spatial reference as e.g. an aerial photograph or a noise map. Especially using sound in combination with a noise map can aid the user in understanding the noise distribution. The repeated presentation of the same information using different media improves the understanding of the viewer (Dransch, 1997). In order to achieve finer display details in term of noise intensity, we used a colour depth of 256 levels. It is well known that human being have a great capacity to differentiate between small colour nuances, but have problems in associating colours which are close or identical, particularly when those colours have same hue (i.e. darkness only varies) and are placed further apart, like it is normally the case when trying to associate a colour on the map with a colour on the legend. In order to help the association process between colours on the map and colours in the legend, we provided a moveable legend. Accordingly, one can drag the legend on a particular map location and move it up and down until one of the colour levels shown in the legend cases is identical with the colour level at that particular map location. Moreover the sound level at the mouse position is shown next to the legend and is changed continuously as well.

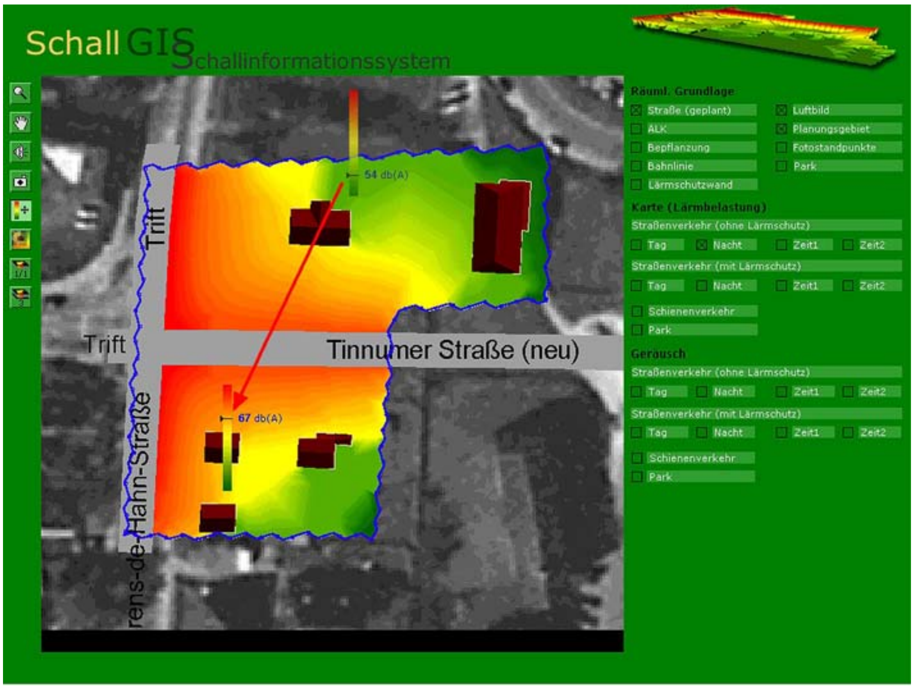

Figure 5. Moveable legend function.

Potential of Acoustic Maps for Urban Noise Planning and Control

Urban noise planning activities involve many people with different knowledge about the phenomenon and its characteristics as e.g. elected officials, urban planners or affected residents (Servigne et al., 1999). To generalize the categorization of users we can speak of experts and novices. Both need information about the spatial distribution of noise in the form of maps to discuss possible alternatives for noise reduction measures. The new visualization tools can help both of them in understanding this complex phenomenon, even if in different ways.

Experts need to compare different noise abatement measures on the basis of effectivity and costs. They also have to consider what happens in other parts of a city if a road is closed for noise reduction. Reduction of noise in one area can lead to increasing noise for more residents in other areas. For this reason we are working at the moment on the development of sophisticated analysis tools using Macromedia Director and Lingo. After the completion it will be possible to overlay a noise map before and after the noise abatement measures respectively and compute a new map showing the positive/negative effect for every location.

The new visualization tools presented above can help novices to understand the noise characteristics, as e.g its continuous distribution and the qualities of sounds from different sources. Especially the combination of audible and visual information can help citizens with no prior knowledge to understand the phenomenon (Dransch, 1997). The visualization tools may be used effectively in a collaborative planning system (Shiffer, 1995) or accessed by a kiosk terminal. Another possibility that has not been investigated until now is the distribution of audible and visual noise information via the internet.

Since noise is likely to increase in the following years as a result of growing traffic and leisure activities, noise management will be in the future as important as air and water quality management are today. To take measures against noise, the actual spatial noise pollution has to be analysed and therefore the use of sophisticated and understandable maps is essential.

Conclusion

In this paper we have presented new methods to visualize urban noise by bringing the traditional noise map into the computer screen and loudspeakers (Yves Guermond, 2000), extending its usability through different tools, e.g. dynamic displays, transparent layers, moveable legend and the merging of different media (animation, sound, interactivity). This research draws upon on the four paradigm shifts in cartography that occurred in the

last four decades, namely the automation, the creation of new digital maps, the so called “democratisation of cartography” and the convergence between the multimedia revolution and internet.
As noise is an important factor for the quality of human life, and is becoming more and more a political issue due to growing traffic and leisure activities, the application of new presentation methods will lead to a better understanding and hence to better decisions concerning noise reduction. The new tools can be applied in urban noise abatement planning to facilitate the understanding of this complex phenomenon for experts and novices.
Realistic sound as a new medium for the cartographic presentation of noise has been suggested by some authors (Wood, 1992; Dransch, 1997), but has never been closely, scientifically examined before. However, reproduced sound with the help of the computer should be used carefully because it just gives an impression of how the sound might be like at a certain location and does not exactly convey the true reality. Therefore the user should be aware of the acoustic generalization process as he should be for reading any map.
Despite the comprehensive research carried out in this project some important research topics concerning the visualization of urban noise have not been tackled yet and remain to be investigated, including the temporal aspects, the internet presentation of noise maps and their user-friendliness.

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