BROADCASTING AUDITORY WEATHER REPORTS – A PILOT PROJECT

Thomas Hermann, Jan M. Drees and Helge Ritter

Neuroinformatics Group · Faculty of Technology · Bielefeld University
Bielefeld, Germany
thermann@techfak.uni-bielefeld.de

ABSTRACT

This paper reports on a pilot project between our research department and and a local radio station, investigating the use of sonification to render and present auditory weather forecasts. The sonifications include auditory markers for certain relevant time points, expected weather events like thunder, snow or fog and several auditory streams to summarize the temporal weather changes during the day. To our knowledge, this is the first utilization of sonification in a regular radio program. We introduce the sonification concept and present our design of the sonification which is oriented at combined perceptional salience and emotional truthfulness. Sound examples are given for typical weather situations in Germany and several prototypical weather conditions which tune to be connected with emotional value. We will report first experiences with this pilot project and feedback of the audience on ICAD since broadcast started in February 2003.

1. INTRODUCTION

Sonification offers the possibility to represent complex high-dimensional data sets in a compact auditory "sound image". Similar to visual displays, where an image is known "to be able to convey more than 1000 words", auditory data images can convey a very complex and and rich situation, both concerning the information side (quantitative) and emotional aspects (qualitative). Since sound evolves in time, it is particularly useful for the presentation of time-variant data series, as they occur in many scientific contexts. However, while visualization techniques are broadly spread and known, only very few people consider sonification or even know about its existence. The reason is, that sonifications occur so rarely in public media. This appears somewhat puzzling, since at least the radio indeed lacks any visual display and can enrich its daily program greatly by using auditory data display.

Thinking about promising applications, we arrived at the following three topics of general public interest: sport reports, stock data, and the weather forecast. We started with the sonification of daily weather forecasts since on the one side this topic found the most resonance with the radio people, and is also a domain where data can be easily obtained on a regular basis. The main benefit for the listeners is that they can follow a complex time-resolved data series of their interest in a short time of some seconds. The benefit for the discipline of sonification is that auditory data display reaches a higher public awareness. This paper introduces our sonification concept which pays particular attention to the qualitative aspects like pleasantness and emotional associations. The pilot project started on February 10, 2003, and we will provide results and an evaluation of public feedback on the project on ICAD 2003 and on our web site [1].

The paper is structured as follows: Section 2 analyzes the task and the data domain, and lists some requisites for the implementation. Section 3 presents two alternative strategies for sonifying the data and compares them along aspects like pleasantness and learnability. Section 4 introduces the concept of emotional markers and presents sound examples for different prototypical weather situations. The paper closes with a summary and remarks about the planned evaluation.

2. WEATHER FORECAST – TASK AND DATA ANALYSIS

Weather is a complex, spatially resolved, chaotic and hardly predictable system that evolves in time. Weather data are collected by satellites, measurement stations, and forecasts are the result of computationally very complex simulation techniques [2]. There is much need for techniques to browse, explore and analyze the resulting long-term spatially resolved time-series, and the capabilities of time-compression makes auditory data display an excellent means for such tasks as well as for the task of comparing the weather in different places or seasons [3].

While these questions are interesting for meteorologists, non-experts are concerned with a very different aspect of weather: how will the weather be tomorrow? Will I have to take an umbrella? What clothes are warm enough? The right weather for a walkaway tomorrow? Obviously, most people have an interest in the local weather over a limited time span into the future. Different from the expert's quantitative interest, the usual listener is concerned with the emotional value and contextual implications, which are not simply assessed from single weather attributes like temperature or humidity in isolation. To give an example, temperatures of 30°C (86 F) can be very nice weather (at low levels of humidity without any clouds) or be a strain (sweltry weather, warm and wet). Any sonification that aims at transporting emotional value with sound in a truthful way must therefore pay attention to the relations of different variables in the high-dimensional "weather vector".

2.1. The Data

The weather vector contains the values for all available weather attributes. In detail, the weather vector is predicted with a resolution of one hour and contains the continuous attributes temperature, humidity, wind velocity, wind direction, rain probability, cloudiness as well as binary attributes for thunder-storm, snow and fog. The snow attribute is actually a nominal variable, since different types of snow can be discerned, ranging from sleet to hail. From those attributes and the weather history, even more features can be derived, e.g. glazed frost, if rain is followed by over-night frost. Such derived attributes will be included in later revisions of the display. Figure 1 summarizes the currently used features.

	temperature [C]	humidity [%]	rainfall [%]	snowfall	windvel. [km/h]	wind direction	cloudiness [%]	thunder	fog
min	−20	0	0	0	0	0	0	0	0
max	40	100	100	1	120	360	100	1	1
type	o	o	o	b	o	−	o	b	b

Figure 1: *Weather features and value ranges; the variable type is denoted as* **o***rdinal,* **b***inary or* **c***ategorical.*

2.2. The Task

The task in auditory weather data display is to turn the daily weather forecast into a sensual experience. In order to be accepted by radio listeners, the sonifications have to fulfill their information requirements. Since both knowledge about the sonification and auditory skills may vary among the potential listeners very widely, it is of crucial importance that the sounds (or most of their constituents) are easily understood even without any tutorial. Additionally, in order to be accepted, sound quality is an important issue.

The task followed by the listeners is to find out how the weather of tomorrow will be like. As mentioned above, the interest will most likely be focused on the relative changes from the actual weather. In addition, information about potentially occurring events like thunder-storms, or glazed frost will be expected. There will be listeners that do not consciously pay attention to the auditory weather forecast. We assume that nonetheless the audio information is processed subconsciously and interpreted according to its basic emotional value. In order to be useful even for those listeners, the sonification has to evoke an emotional association, e.g. by using nicer sounds for better weather conditions.

2.3. Media Constraints

Limitations on the concrete realization of auditory data display arise from the media as well as the listening context. The most important limitation is given by the available time, which is usually limited by the radio station's tight schedule. In radio programs, any (potentially) inconvenient passages may not last longer than some seconds in order to prevent the listeners from changing the station or turning the radio off. With the Bielefeld Campus Radio HERTZ 87.9, we agreed on a 12 second time frame, resulting in a high temporal compression of 2 hours/second.

Another issue is given by the usual receiver situation. One can not rely on stereo information, since most people still listen to the radio in contexts where spatial sound resolution is very limited. Also, the broadcast audio signal is processed by a dynamic compressor which reduces the available dynamical range.

2.4. Listener expectations

The sonifications are integrated into the regular radio program and will frequently reach new and unexperienced listeners, which may be swamped with the complexity of the sonifications. Assuming that the listeners are most likely novice in using an auditory data display, this demands the auditory display to be more or less self-explanatory. Thus even if the sonifications show great value for highly trained listeners they need to be valuable and acceptable also for naive listeners, indicating the high importance of an intuitively graspable display that at least uses pleasant sounds. The importance of pleasantness and high-fidelity may not be underestimated – they even dominate the factor of perceptual salience. The most important aspect is that the listeners like the sounds and enjoy them and if a more pleasant sonification can be found at the price of reducing the conveyed information only slightly, it will be good advice to prefer it. So the factors are a little differently weighted than in many other research contexts where perceptual factors dominate.

2.5. Teaching and Learning

Human's capabilities in learning to adapt to new auditory patterns are very remarkable and in comparison to the novice listeners experience, some teaching and listening practice can enhance the user's profit and understanding of the auditory display significantly. We are very keen on observing how the daily practice changes the radio listener's valuation of the auditory data display, which will be subject to an ongoing evaluation.

Of course, it is necessary to bring the listener carefully in touch with this new medium. The radio station has produced jingles, reports and radio features to explain the display in detail. The first jingle was like "ping–30 degrees, ping–50 degrees, ping–70 degrees – and so will the weather sound tomorrow!" where the 'ping' is replaced by the proper temperature marker sounds. Such a jingle is frequently prepended to the sonifications. For evaluation, we will ask for postal cards with comments, connected with a lottery. In addition, we promote e-mail comments to our web site weather@sonification.de and we plan an Internet questionnaire.

3. DISPLAY DESIGN

The weather forecast sonification uses a data set containing for each hour between consecutive midnights the 9-dimensional weather vector as shown in Figure 1.

In our very first approach we used different continuous sound streams for representing the different features, mapping value variations to pitch and level variations. The resulting sounds are clearly recognized as synthetic and although the pitch variations allow to follow clearly the temporal evolution, the display fails to convey a vivid image about the complex weather state. This display serves as a "bad example". Such undifferentiated display strategies may be suited if no domain knowledge about the data is available, which here is not at all the case. From the aspect of conveying information, this sonification is not that bad, however, it definitely neglects most of the relevant aspects like pleasantness and is not self-explanatory. Sound examples are provided on our web site [1].

Our finally used sonifications are a product of gradual fine-tuning a multi-stream auditory display on the basis of auditory icons [4], since these sounds support their interpretation from their connotation and metaphoric association with the thing or property being signified. However, a careful selection of these auditory icon sounds has to be done to avoid masking effects and interference. The following streams are combined to the sonification:

- **Time Markers:** The sonification time was chosen to be 12 seconds, which agrees both with the radio demands and the perceptual demands. To help the listener orienting in the sound, we provide "time marker sounds", auditory events that are connected with time points during the day. Our sonifications represent the data from midnight to midnight,

and we decided to use markers on a 6 hour grid. Neither begin nor end have to be marked, so the first event is played at 6 a.m., resp. after 3 seconds of sonification time. A ringing alarm clock sound is easily associated with waking up and used at this time. A cockcrow was considered but rejected since its duration is too long. For noon, a church bell is used. In lack of typical sounds for 6 p.m., we repeat the alarm clock sound. All sounds are spectrally complex so that a soft low sound level suffices in the final mix.

- **Wind:** The wind data are two-dimensional containing wind velocity and direction. Wind velocity can be easily conveyed by using wind sounds. We synthesize them by using a two-pole resonator with center frequency (pitch) and bandwidth controls. Both wind sound level and wind sound pitch are increased with wind speed. A smooth interpolated random variation of pitch at a rate of 1 Hz is used to make the wind sound more convincing. The bandwidth is chosen to be about 60 Hz, so that wind is pretty well isolated in the spectra and does not interfere with the other streams. Wind direction is regarded as a secondary attribute. We simply use lateralization, mapping west winds to the left and east winds to the right audio channel. Of course, stereo receivers are required in order to profit from this additional attribute.
- **Rainfall:** The rainfall is given as a probability for rain during an hour. Since there is no information about when it will rain, a stochastic rain allocation is used such that the relative duration of rain sounds during a 4 hour time interval equals the averaged rainfall probability. Practically this is achieved by playing rain sounds of different length distributed randomly during the day according to the data. Selection of the rainfall sound posed many difficulties: most rain sounds interfere with wind and disturb attendance of the other attributes. Finally we selected a rain sound where isolated drop sounds can be very clearly perceived. The sound is replaced by a snowfall texture if required.
- **Temperature:** There is no real-world sound associated with temperature. Since, however, temperature is the attribute where quantitative evolution is most likely of interest, we ended with using a parameter mapping using hourly spaced instrument sounds (resp. 0.5 sec sonification time between tones) using a pleasant instrument. Experimenting with different instrument classes we found a vibraphone tone most pleasant. Its exponential decay facilitates to follow changes, since the ending overlaps with the next tone. The sound has a short attack phase and an internal rich overtone spectrum, making it suitable for the following signal modifications. We use a pentatonic scale in order to improve the pleasantness of the sound. This causes unchanging pitches if temperature variations are less then about 3°C (5 F). Frosty temperatures are represented with a harder timbre than vibraphone, using a xylophone sound.
- **Cloudiness:** How shall a cloudy scene sound like? Less bright! A clear summer day may sound clearer, more brilliant, a cloudy summer day causes a curbed (damped) impression. We first considered to apply a bandpass filter on the sonification (without reverb) to express cloudiness. However, the results were not convincing, especially on bad portable receivers. The same tendency can however be implemented by adding a low continuous bass tone (cloudiness controlling level) and a brilliant "sound carpet" for sunshine. However, this sound has to be very dim in comparison to the other streams.
- **Atmospheric Humidity:** The sonification so far is already very rich, so that it is questionable how far the stream addition strategy may further work. For humidity, however, there is a quite good metaphoric association in sound, precisely in sound effect: reverberant environments are often called "wet", whereas lack of reverberation is coined "dry". In this sense we use atmospheric humidity to control a reverberator whose input is given by the temperature stream explained above.
- **Events:** Lots of weather events can occur: thunder, hail, fog, glazed-frost. We tried to find associative sounds, which was easy for hail and thunder. The events are mixed at timestamps where they do not interfere with other marker sounds.
- **Emo-Markers:** Emotional markers are additive elements that are integrated into the sonification to evoke certain emotional effects connected with typical weather conditions. They are introduced below.

A graphical illustration/score of the weather sonification is shown in Figure 2.

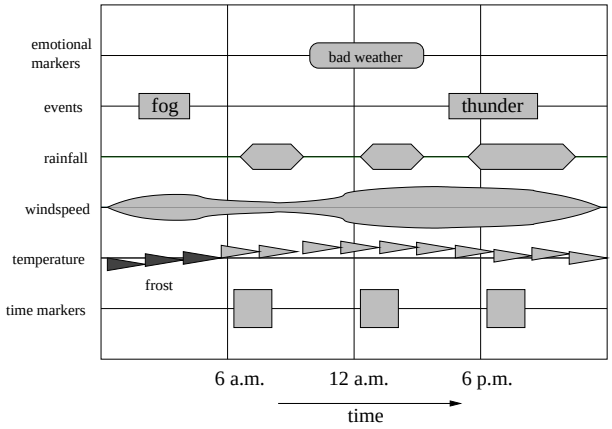

Figure 2: *Illustration of the weather forecast sonification. Along the y-axis, the different streams are listed. Humidity and wind direction are missing in the diagram since they do only modify existing sounds.*

4. SOUND EXAMPLES

As introduced above, the weather state is a high-dimensional vector which can be regarded as a point in a 9-dimensional vector space. The hourly changing weather during the day specifies a trajectory in weather data space. The data space is only sparsely filled due to interactions and correlations between the attributes. A projection on the first two principal components delivers a 2D-plot where hourly weather vectors are represented as points as shown in Fig. 3. In addition to the data point, certain prototypical weather situations can be associated with emotional values. Several of those emotional prototypes as well as a trajectory for one day are shown in the plot that we call an *emo-map*. For in-

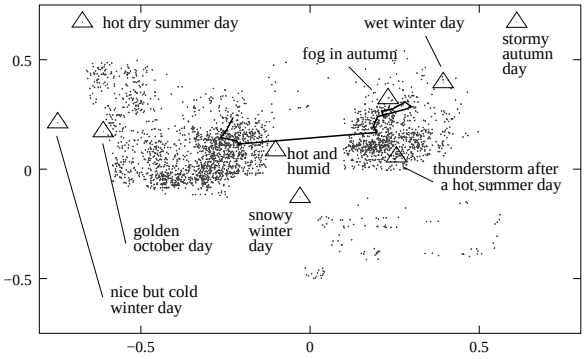

Figure 3: *The Emo-Map with typical weather states and prototype markers. Since the axes are principal axis, their interpretation with respect to the attributes is impossible.*

stance think of a bright cloudless midsummer day, low humidity, no rain, not too hot. This prototype has (for most people) a very positive association. In contrast, think of wet rainy chilly harvest days with their depressing connotation. Using the prototypes, the weather data space can be tessellated into regions using the nearest neighbor relation [5, 6]. The closer a weather state vector comes to a prototype, the more likely will this emotional association dominate. An important aspect is the distance measure to be used in this space. Sphering the data set is a suited pre-processing but can cause unimportant features like wind direction to have a great influence on distances between the prototypes. For our current emo-map we simply neglected wind direction.

If the weather trajectory comes nearest to a prototype and falls below a threshold radius, an emotional marker sound is played. Besides emotionally positive or negative marker sounds, specific sounds can be found for certain prototypes, e.g. a wet cold November day is associated with having a cold. A sneeze is a fairly matching auditory icon. All sounds are available on our web site[1].

Some typical weather trajectories that pass an "emo-prototype" during the day are listed below and the corresponding forecast sonifications are provided on our web site. The emotional value for the emo-prototypes is estimated from interviews with some few people. First preliminary emo-marker sounds are indicated which however are subject to our currently pursued fine-tuning.

- *hot dry summer day*: tired, forceless, exhausted, an indifferent emotion – panting sound, cricket songs
- *warm dry summer day*: positive emotion, happy, optimistic – a bird sound associates a walkaway occasion.
- *hot and sweltry summer day*: exhausting – a 'sigh' sound is played
- *nice cold winter day*: positive emotion – e.g. uprising sound with shiver/strong vibrato
- *golden october day*: positive emotion – uprising quint with an pleasant organic sound
- *snowy winter day:* negative, calm, indifferent – a shudder/shiver sound
- *fog in an autumn morning*: mystic and curbed – distant reverberant scream
- *thunderstorm on a hot summer day*: wild, anxious – maybe a kettledrum sound
- *wet winter day*: depressing, pessimistic, negative – a downscale tritonus interval, crying or weeping sound
- *stormy rainy autumn day*: depressing – a smooth diminished chord

The example sonifications suggest that a wide range of distinctive qualitives contained in weather can be transported by sound. Even non-trained listeners will be affected by the sound since the emotional associations of its constituents were particularly considered.

5. CONCLUSIONS

We presented an auditory weather forecast sonification, which is being used for extending the weather report in a regular radio program in collaboration with the Campus Radio Hertz 87.9 in Bielefeld, Germany. The sonification is designed to meet several requirements, coming from the radio broadcasting side, the anticipated listeners' interests and the domain of the given data.

The sonifications allow to follow a 24 hour forecast in 12 seconds, using mainly auditory icon-based streams, augmented by many marker sounds to represent time labels and weather events. As an especially new perspective, the sonification addresses the issue of qualitative display design and emotional value by paying attention to the emotional effect of sound to the listener: nice weather is intended to sound nice – besides conveying the information. For that purpose, the vector space was divided in cells and emo-markers were introduced that are played according to their distance to the emo-prototypes.

The sonifications have been demonstrated with sound examples for some typical weather conditions. Broadcasting started in February 2003 and we will report results, feedback, user comments and learning effects as well as the press echo at ICAD 2003.

6. REFERENCES

[1] T. Hermann, "Sonification for exploratory data analysis – demonstrations and sound examples," `http://www.techfak.uni-bielefeld.de/~thermann/projects/index.html`, 2002.

[2] G. Cats and L. Wolters, "The HIRLAM project," *IEEE Computational Science & Engineering*, vol. 3, no. 4, pp. 4–7, 1996.

[3] J. H. Flowers, L. E. Whiter, D. C. Grafel, and C. A. Kotan, "Sonification of daily weather records: issues of perception, attention and memory in design choices," in *Proc. of the 7th Int. Conf. on Auditory Display*, ICAD 2001, Helsinki, pp. 222–226, 2001.

[4] W. W. Gaver, "Using and creating auditory icons," in *Auditory Display*, G. Kramer, Ed. ICAD, 1994, pp. 417–446, Addison-Wesley.

[5] B. D. Ripley, *Pattern Pecognition and Neural Networks*, Cambridge University Press, 1996.

[6] B. V. Dasarathy, *Nearest Neighbor Norms: Nearest Neighbor Pattern Classification Techniques*, IEEE Computer Society Press, Los Alamitos, CA, 1991.

[1] `http://www.sonification.de/weather.html`