image data sonification,
medical image data,
ECG,EEG, data analysis

Maria BERNDT-SCHREIBER*, Wojciech LESIŃSKI*,
Łukasz TRZCIAŁKOWSKI*

IMAGE DATA SONIFICATION IN MEDICINE

A procedure of image data sonification has been described as an alternative to the traditional graphical visualization approach. The state of the art and the essential features of the method in various data analyses have been presented. Original interface designs have been introduced and potential applications in medical practice have been illustrated and discussed.

1. INTRODUCTION

Sonification presents information using a transformation of the investigated data into sound thus providing a new insight and often a deeper understanding of the data or relevant processes by listening. It is an alternative technique to data analysis based on two- or three- dimensional graphics plotting and associated statistics. All the graphics displays are based on the human sense of vision, whereas the sonification approach takes advantage of the human sense of hearing, so far not fully exploited at computer interfaces.

During the last two decades we have observed enormous progress in the scientific visualization techniques in many fields. On the other hand, we also observe an increasing number of datasets (often of high dimensionality) collected and stored digitally which require new intelligent processing procedures. They concern both micro- and macro-scale problems in various areas and refer to dynamical processes and time series analysis essential in many fields of medicine as well. Sonification may be one of the proposals for such sophisticated data analysis referring to the specific features of the human hearing perception (not always comparable to the features of vision). Its importance is rapidly growing since the research in the field of sonification is closely related to many interdisciplinary investigations and essential problems in data mining, exploratory data analysis and human-computer interactions. In particular, sonification provides a flexibility required in the context of exploratory analysis of high dimensional data, where different ”views” on the data set are necessary. There are many open issues indicated in the recent research approaches worth focusing on. The number of publications covering the subjects is rapidly increasing each year (comp.e.g. [1-7] and references therein) and they concern various fields of applications, including crucially important medical areas.

The main arguments in the recent developments refer to the fact that humans are adapted for interacting with their physical environment making use of all their senses and, in particular, with sound explorary interaction quite a different context may be gained, not obvious in the visual rendering. It is worth noticing that with Euclid’s axioms of geometry our basic mathematical concepts are related to spatial principles and, in consequence, to vision-based science with comparatively simple graphical rules. There are no auditory elements in the most important physics concepts based upon vector spaces. In fact, the domain of audio physics started with the availability of modern computers. The auditory displays offer an interesting alternative to visual symbols in plots. The audio counterpart of the graphical point is in fact an acoustic event, which simultaneously manifests various attributes, such as pitch, duration, spatial location, timbre etc. On the other hand, it should be noted that our human perceptional appartus is tuned to process combined audio-visual information. According to several authors, the aim for the future should be real-time multimodal interactive explorary systems, providing interactive manipulation of high dimension data sets transformations into sound.

For this reason the purpose of our paper is to present designs of interactive environments to start up with some data sonification experiments in various fields, including some medical data sets. In the following sections we describe the undertaken attempts and discuss the applications results as well as conclusions for future studies.

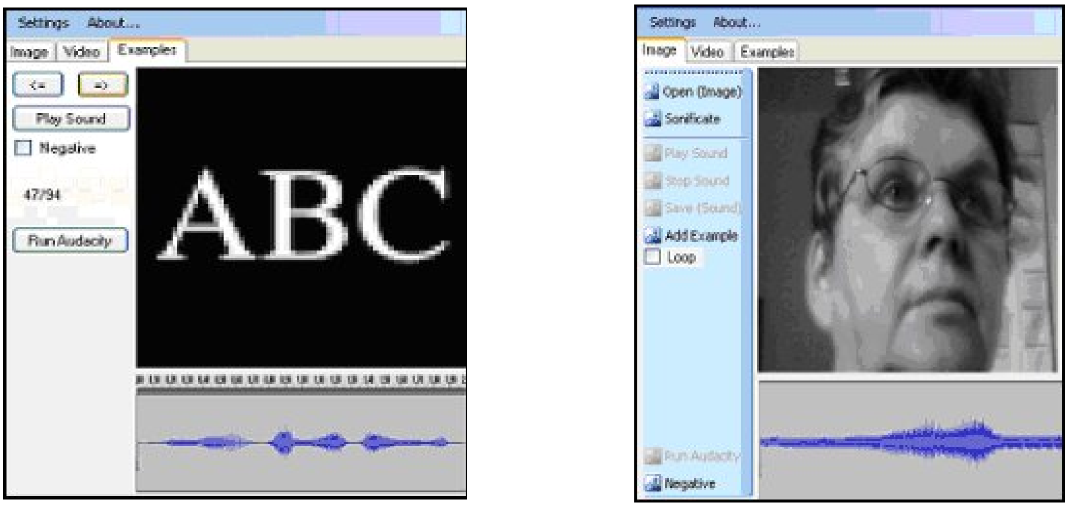
2. ALGORITHMS AND SOFTWARE INTERFACE DESIGNS

The basic algorithm for data sonification is comparatively simple and has been exploited by many authors. It is described in the vOICe application [8] and also available in the rudimentary form in the Mathlab software [9]. Therefore our main efforts have been focused on the appropriate environment designs. Eventually two applications have been proposed, addressed to two different groups of potential users, but with some comparable basic functionalities. At the first stage both the applications, described below, have been successfully tested by comparing their results with those generated by the vOICe application and the Matlab software, respectively.

The first one Image Sonification (IS) has been inspired by the vOICe application algorithm. It is potentially adjustable as a tool helping the visually impaired people – with a special option of creation an extended vocabulary of the so called soundscapes for a new user which is not available in the original version of the vOICe software [8]. In the basic implemented algorithm the image data are analyzed as matrices, and scanned accordingly along the columns from the left to the right. The

* Faculty of Mathematics and Computer Science, Nicolaus Copernicus University, Toruń, Poland.

row locations are interpreted as the sound frequencies. The quantization levels of the pixels are interpreted as the sound intensities, accordingly. The main parameters for the sound display, provided as default ones, may be also set up by the user, according to her or his preferences. The IS application has been prepared in the **C#** language and its main interface frame is presented in the Figure 1. (A). It provides unique sonifications of both static images as well as snapshots taken with a standard web camera – as illustrated in the Figure 1. (B).



(A) (B)

Fig. 1. The main interface frame for Image Sonification IS application (A) and its workspace (B), respectively.

The second application called Data Sonifier (DS) – has been built as a tool for various numerical data explorations (being not directly available in the original vOICe programme) - using the standard algorithm for preprocessed data sets, which may be presented in a compact form as below:

```
coef = max_abs(data_in) / max_playable_note;
for i = 1 .. data_in.length
        scaled[i] = data_in[i] / coef;
        play_note(scaled[i]);
```

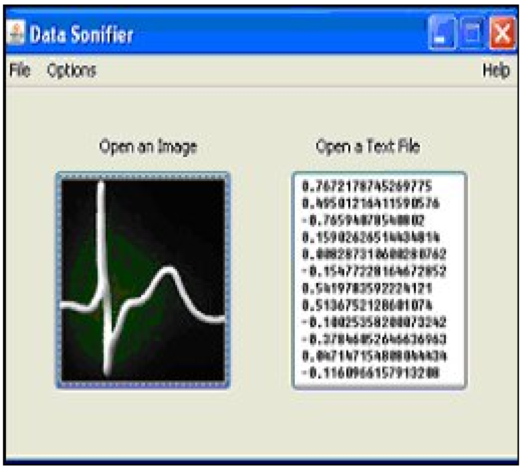
where:

data_in – represents the input data table

max_playable_note – the maximum playable sound

max_abs(data_in) – element of the maximum absolute value

The main idea of this algorithm is based on applying a prescaling procedure for the input data to represent them with the use of the midi interface. The application DS has been prepared in Java using SDK Eclipse. Its main interface frame is presented in the Figure 2. (A). With standard functions typical for sound processing software available it provides a possibility to explore various sonified data (including images, graphs and text files) in the user friendly way with a choice of instruments available in the midi interface – compare the workspace in the Figure 2. (B).

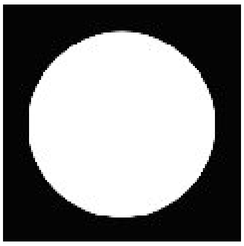


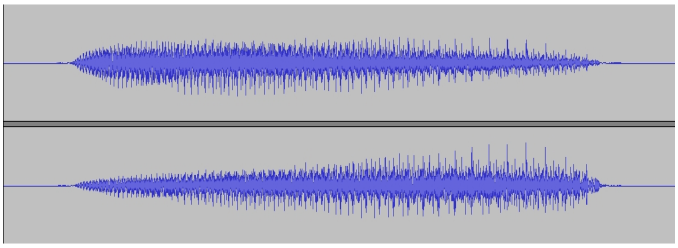
(A) (B)

Fig. 2. Main interface frame for Data Sonification application DS (A), and its workspace (B), respectively.

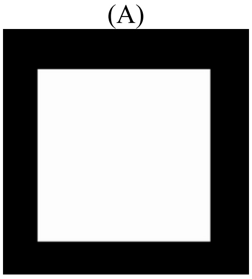
3. RESULTS AND DISCUSSION

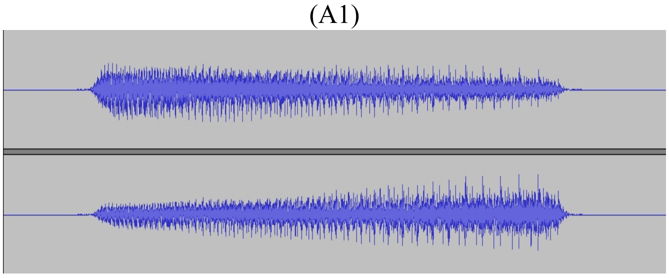
The application Image Sonification (IS) has been designed as a tool supporting visually impaired people. At the first stage it provides a possibility to create individual vocabulary of various images representing e.g. different basic shapes, as illustrated in the Figure 3, below.



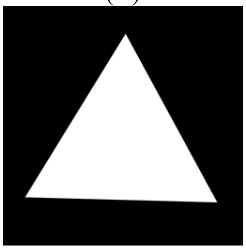


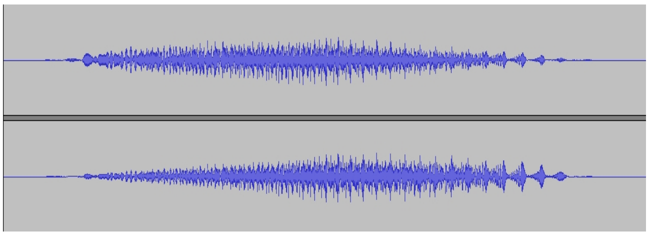
(A) (A1)





(B) (B1)



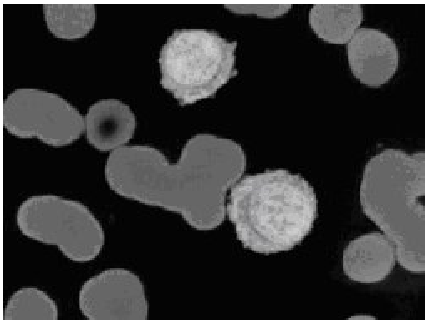


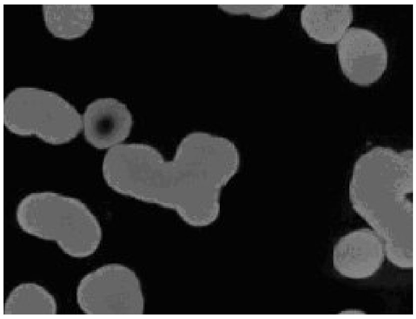
(C) (C1)

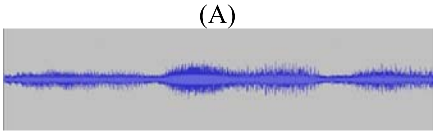
Fig. 3. Sample soundscape vocabulary generated by IS for basic shapes images. The standard shapes: circle (A), square (B) and triangle (C) are associated with different sounds, illustrated here as different stereo waveforms (A1), (B1) and (C1), respectively.

In the figure sample images of several basic geometrical shapes (here: a circle, a square and a triangle) are associated with the generated different sounds, illustrated by appropriate waveforms (here: for the stereo wave format). As it can be seen in the Figure 3 the different shapes may be recognizable by the appropriate different waveforms. It does require some training of the user though, but gradually more and more complicated patterns may be properly recognized by listening to the associated emitted sounds.

The same IS software may be also applied to microscope image series analysis. The cells depicted in the image presented in the Figure 4. (A) are from a patient with plasma cell leukaemia [10]. The associated waveform is shown in the Figure 4. (A1). As it can be observed in the Figure 4. (B) and appropriate waveform Figure 4. (B1) a change pasted in the original image has generated a different sound, thus providing its detection.


(A)


(B)


(A1)

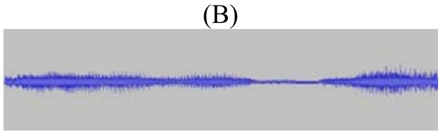
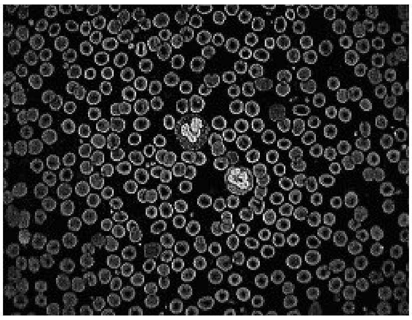
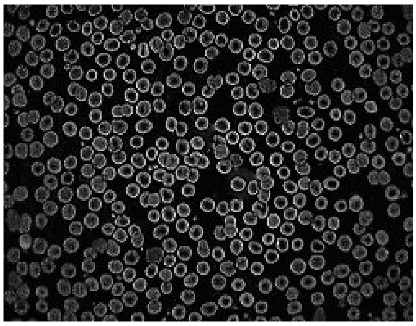

(B1)

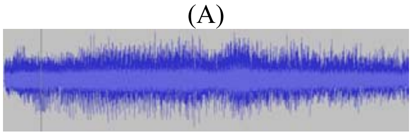
Fig. 4. Part (A) a sample microscope blood cells image [10] and its generated sound waveform (A1). Part (B) – a modification of the original image (A) and its associated changed waveform (B1), respectively.

A similar situation is presented in the Figure 5 illustrating a normal blood smear [11], below. One can observe, following the same notations for the original Figure 5.(A) and the modified Figure 5.(B) image versions, that even minor changes may be also detectable in the resulting waveforms of Figure 5.(A1) and Figure 5.(B1), respectively, for the generated mono sounds. It is worth to notice that, following the assumptions made in the original vOICe application, the IS software presented here also works for greyscale images of the size 256x256 thus enabling a quick procedure for serial images similar to the shown sample microscopic ones.

The second proposed application, called Data Sonification (DS), represents quite a different approach and it is mainly dedicated to the sonification procedure of numerical data available in the form of either tables or text files and graphs. Formally it accepts the following types of files**: txt, csv, bmp, gif, jpeg**. After a preprocessing scaling procedure for the studied data set (see Figure 6 for sample ECG data - Fig.6. Part (a), and blood pressure changes data, Fig.6. Part (b)), the software explore the data taking advantage of the standard


(A)


(B)


(A1)

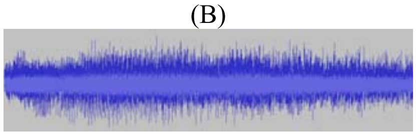
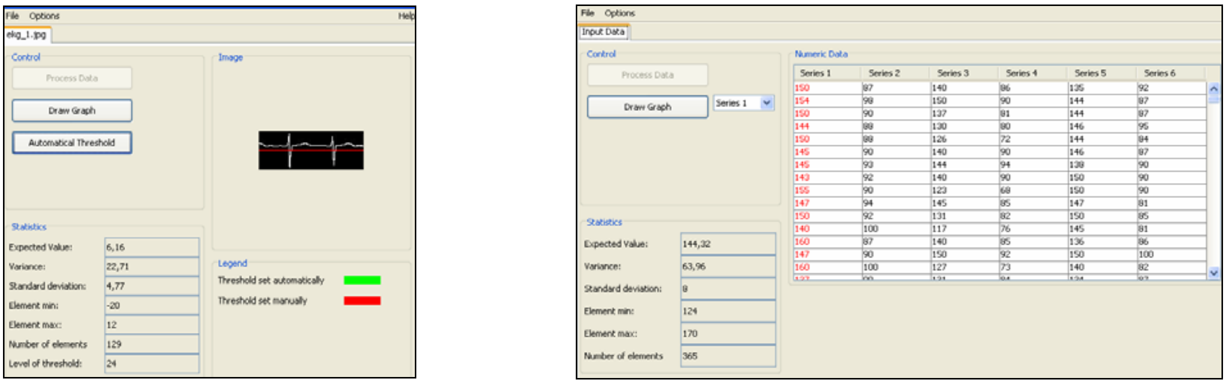

(B1)

Fig. 5. Part (A) a normal blood cells smear [11] and its generated sound waveform (A1). Part (B) – a modification of the original image (A) and its associated changed waveform (B1), respectively.

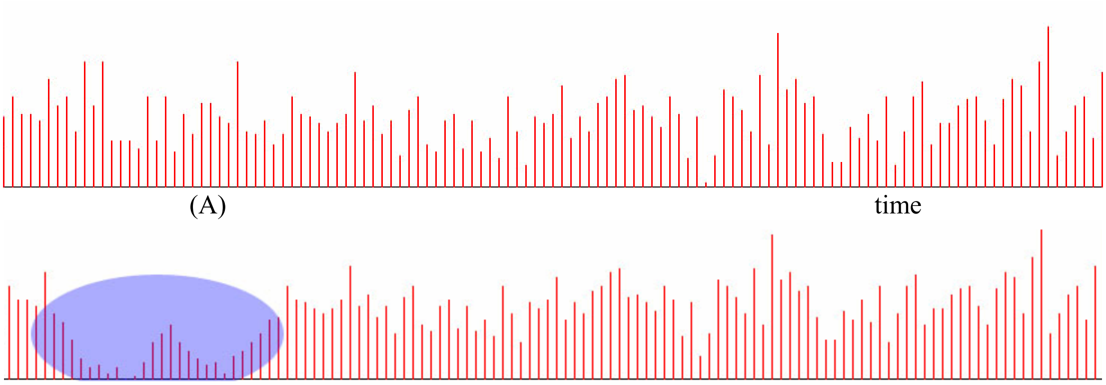
midi interface, which provides a choice of different eleven instruments for the display (comp. Fig.2 (B) above). The resulting sound representations may be saved in the following formats**: wav, mid, ogg** and **mp3.**



(a) (b)

Fig. 6. Data Sonification application. Part (a) - input image data for a sample ECG graph. Part (b) - input data for blood pressure changes [12].

We have tested the DS application using sample ECG and EEG data available in the internet to find that there are evident differences in the resulting generated sounds for different subjects and also for modified data for the same subject. In particular, we have carried on computer experiments with the available data set of annual blood pressure changes [12]. The data consisted of regularly registered blood pressure values measured systematically in the mornings and evenings for the whole year 2007. A sample graph for some extracted values registered in time is shown in the Figure 7. (A), below.



(B) time

Fig. 7. A sample graph fo some extracted blood pressure data changes registered in 2007 [12]. Part (A) - original data. Part (B) - modified data indicated by the shaded oval shape.

We have carried on experiments with the data to confirm that the changes in the values, similar to those illustrated in the Figure 7.(B) by the shaded oval shape, may be verified by the generated sound waveforms.

4. CONCLUSIONS

Our preliminary computer experiments with the elaborated sonification software have demonstrated that it may appear useful in some medical data analysis. We have carried on preliminary experiments for various types of data essential for medical practice indicating that the sonification procedure results may potentially enhance the data analysis. The approach, however, require further tests for carefully selected serial medical data exploration, necessarily with an extended clinical expert assistance on one hand, and a more sophisticated generated sound analysis, on the other hand.

BIBLIOGRAPHY

[1] HÖNER O., HERMANN T.,GRUNOW C.,Sonification of Group Behavior for Analysis and Training of Sports Tactics,Proceedings of Internationla Workshop on Interactive Sonification, Group Bielefeld 2004

[2] BAIER G., HERMANN T., The Sonification of Rhythms in Human Electroencephalogram, Proceedings of ICAD 04-Tenth Meeting of the International Conference on Auditory Display, Sydney, Australia, July 6-9, 2004

[3] BAIER G., HERMANN T., LARA O.M., MÜLLER M., Using Sonification to Detect Weak Cross-Correlations in Coupled Excitable Systems, Proceedings of ICAD 05-Eleventh Meeting of the International Conference on Auditory Display, Limerick, Ireland, July 6-9, 2005

[4] BAIER G., HERMANN T., SAHLE S., STEPHANI U., Sonified Eplileptic Rhythms, Proceedings of the 12th International Conference on Auditory Display, London, UK, June 20-23, 2006
[5] BOVERMANN T., HERMANN T., RITTER H., Tangable Data Scanning Sonification Model, Proceedings of the 12th International Conference on Auditory Display, London, UK, June 20-23, 2006
[6] HERMANN T., BAIER G., STEPHANI U., RITTER H., Vocal Sonification of Pathologic EEG Features, Proceedings of the 12th International Conference on Auditory Display, London, UK, June 20-23, 2006
[7] HERMANN T., BUNTE K., RITTER H., Relevance-Based Interactive Optimization of Sonification, Proceedings of the 13h International Conference on Auditory Display Display, Montreal, Canada, June 26 - 29, 2007
[8] http://www.seeingwithsound.com/ - the vOICe application of Peter Mejier
[9] http://www.mathworks.com/ - Matlab software
[10] http://www.wadsworth.org/chemheme/heme/microscope/plasmacell.htm - sample plasma cell leukemia images
[11] http://www.siumed.edu/~dking2/intro/bldcells.htm - sample normal blood smear images
[12] blood pressure data for 2007 [a private source].