ADDING SOUND TO MEDICAL DATA REPRESENTATION

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ABSTRACT

Some preliminary results of a project aiming to develop tools for adding sound associated to medical data are presented. The description of our sonification procedure is followed by two different examples. The first refers to monitoring the heart rate (HR) during exercise, either in clinical settings or in self monitoring conditions. The second example is an application from molecular biology / cellular kinetics, for analysis of protein-protein interaction, with a specific reference to a computer simulation of P53 – MDM2 interaction, which exhibits, under certain conditions, an oscillatory behavior. Pending issues and future work are finally discussed.

1. INTRODUCTION

There are a couple of decades since the use of sonification for representation of medical data has been tried, especially for biosignals [1]. Since then, both the methodology and the technical support showed a marked development [2].

The high potential of sonification procedures to supplement visualization and to add valuable information is obvious. Starting from these premises we initiated a project entitled "Adding Sound to Medical Data" [3]. This paper is a short progress report on this project and describes some preliminary results by two examples.

(1) Heart Rate (HR) monitoring during exercise. The professional equipment follows-up various parameters including HR, with warnings when some parameters exceed preset values (thresholds). But this information is mostly visually displayed and the patient is usually kept passive. We have developed an application to add sounds for various thresholds [4]. An extension of the application for the self monitoring of the HR during daily individual exercise has also been tested.

(2) Cellular kinetics – protein-protein interaction. There are several advanced tools used in molecular biology for simulation of cellular kinetics. Usually the number of parameters and variables is very large and, frequently, some values are not known, hence, quite often one has to try several sets until finding an acceptable system behavior. Adding sound to detect potential sets which would yield some looked-for evolutions (like oscillations) might complement the visualization in the exploration phase. In the present phase of our work, for each tested parameter the scale of values is divided into a number of zones, each zone is explored and the sound is produced only if oscillations occur.

2. METHODS AND RESULTS

There are several sonification techniques based on mapping the physical parameters of the data (signal), usually trying to obtain a sonic representation close to the original data.

2.1. Sonification procedures

(a) Pitch. In our approach, partially published [3], the central paradigm was the correspondence between the sound pitch (f_i) and represented datum (normalized value [0,1] of signal amplitude y_i). We have chosen the usual log/exponential scale: $f_i = f_0 \times 2 \wedge (y_i)$, $f_0 = 523$ Hz (C4), (1).

Three major sonification levels have been defined:
- acoustic level – with a continuous frequency spectrum (f);
- sonic level (S) – with discrete spectrum, from musical scale;
- musical level (M) – multichannel, introducing rhythm and harmony. Level M will not be referred in this paper.

We further split the acoustic level into two (sub)levels:
- continuous representation, called also (sub)level A: for two neighbor points (t_i, f_i) and (t_{i+1}, f_{i+1}), the frequency will vary continuously from f_i to f_{i+1};
- quasicontinuous (sub)level Q representation: only the frequency f_i will be produced for the interval dt = (t_i, t_{i+1}), followed by f_{i+1} for the next interval dt and so on.

(b) Sound duration. For HR monitoring, a sound had a duration equal to the interval between two consecutive R waves of the electrocardiogram ECG (RR interval). However, the sound was displayed in different ways, depending on the warning levels/zones, either as a unique sound or with saccadic short interruptions (0.02 RR). For cellular kinetics the duration was computed from the total duration of the acoustic display chosen by the user.

(c) Sonic display duration. For monitoring in clinical settings, the sonic display was continuous for the entire exercise test (6-10 minutes). The version for self monitoring has the sound display only for the first four heart beats after any crossing of a threshold, thus reaching the warning purpose but avoiding the boring background during the entire exercise (10-30 minutes).

2.2. Data

2.2.1. HR monitoring during exercise.

We used data recorded with Labtech ltd. Cardiospy v5.02.02 in clinical tests [5], respectively records from the pulse oxymeter CMS50D plus [6]. The thresholds have been set according to the guidelines of American Council on Exercise,

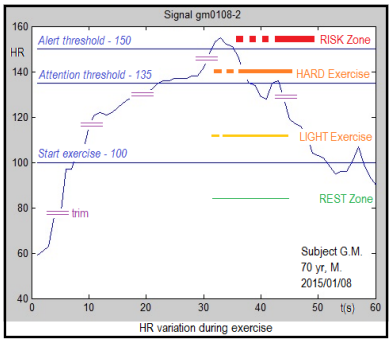

Fig.1. HR zones during exercise and sound scheme.

using Karvonen relations [7]. The three thresholds separate four exercise levels: quasi-rest /[start threshold]/ aerobic mild exercise /[attention threshold]/ hard exercise anaerobic zone /[alert threshold]/ risk zone, with HR > HRmax. Each level (zone) has a specific intensity, from very low to loud, and saccadic display (no saccades / 1 / 2 / 3 saccades). The original record was trimmed, keeping the regions comprising transitions between zones. An example is given in fig.1 and the sonic displays can be downloaded from [8]:

- the 1S type displays only one pitch (f_0), the zones differ only by saccades and intensity (ratios 1/8, 1/4, 1/2 and 1);
- the 3S type has 3 transitions, having 4 frequencies for the 4 zones, multiples of f_0: 1 / 1.2 / 1.33 / 1.6;
- the MS type displays each sound with a pitch depending on HR, computed with relation (1).

The sound intensity was also set to the four zones, from very low / low / medium / high.

2.2.2. Cellular kinetics – protein-protein interaction

The application for cellular kinetics started from our previous work about regulation of protein synthesis, particularly from some interesting results obtained in the simulation of P53 synthesis. As this protein plays an important role in growth control, apoptosis and oncogenesis [9], it has been intensively studied and a lot of experimental values were available. Its synthesis is modulated by another protein, MDM2, whose synthesis gene is controlled by P53, yielding a loop. We built a simple model with four differential equations [10], estimated the values of most of the parameters involved and tried to fit the values of the unknown parameters to match the experimental data. It is not an easy work as, besides the fact that 4 to 6 parameters had to have been browsed, the intimate mechanisms are not known and several hypotheses had also to be considered: is gene activation a continuous or stepwise process, what delays have to be introduced for transcription or translation, for crossing the nuclear membrane and so on. A first good support came from a facility to interactively change parameter values during simulation [11] to which we tried now to add sound.

The sonification was performed in two ways:
(1) taking the concentration of one component (f.i. protein P53) as sonified variable and following the A, Q or S procedures, as described above; this was extended also for two variables at a time, as stereo acoustic display;
(2) a simpler and easier identification of oscillatory trends (damped waves or sustained oscillations) was obtained by detection of extreme values (maxima and minima) and their sonification; the data could be compressed and exposed for each simulation in just 4-5 seconds.

The project is ongoing and the results presented above are still preliminary. Our package comprises a couple of script programs and several functions, built on MATLAB R2011b platform, for sonifying a signal in levels A, Q and S. Some modules developed by Shutte were welcome [12]. For the examples presented above the sounds can be displayed by accessing reference [8]. More data are periodically added on this site.

3. DISCUSSIONS AND CONCLUSION

The results showed a good performance of the system for recognition of heart rate (HR) variability; there is clear distinction between exercise zones. Our system is still off-line, we have worked with recorded signals; in the next phase the system will be online. We also intend to extend the monitoring including the extra systoles and the depression of the ST segment of the ECG signal (important in coronary diseases).

For simulation programs in molecular biology, the extensions will cover the inclusion of more than two sounds, with interactive control of temporal compression and pitch scale control. The theoretical support for detection the attractor's regions will allow sonification of the phase diagram.

We tried to approach sonification of medical data (biological signals or simulated cellular processes) from the end user point of view and demonstrated its potential to add more information in both monitoring heart rate evolution during exercise, or in the routine work of browsing a multitude of potential data sets which can account for experimental data in molecular biology.

4. REFERENCES

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