Sonification of Heart Rate Variability Data

Mark Ballora
Faculty of Music
McGill University
555 Sherbrooke St. West
Montreal, QC H3A 1E3 Canada
+1 514 398-8391
ballora@music.mcgill.ca

Bruce Pennycook
Faculty of Music
McGill University
555 Sherbrooke St. West
Montreal, QC H3A 1E3 Canada
+1 514 398-3862
pennycook@ist.mcgill.ca

Leon Glass
Dept. of Physiology
McGill University
3655 Drummond St. Rm 1118
Montreal, QC H3G 1Y6 Canada
+1 514 398-4338
glass@cnd.mcgill.ca

ABSTRACT
Heart rate variability refers to the analysis of variations in the heart rate over extended periods of time. Heart rate fluctuations can be readily measured from an electrocardiogram and are thought to provide important insights into cardiac function. This project explores the question of whether cardiological diagnoses can be aided by an auditory display. The data is sonified with the software synthesis program SuperCollider. A graphical user interface allows users to optimize playback by controlling a variety of sonification parameters.

Keywords
sonification, auditory display, cardiology, heart rate variability, nonlinear dynamics, software synthesis, SuperCollider

DESCRIPTION

Heart rate variability data sets consist of a one-dimensional vector which contains a series of values representing interbeat interval times. Heart rate fluctuations can be readily measured from an electrocardiogram and are thought to provide important insights into cardiac function. There have been a large number of different statistical measures proposed to evaluate heart rate variability and there is not agreement as to which are the most useful in explaining the erratic changes in heart rates, even from subjects at rest. This project explores the question of whether cardiological diagnoses can be aided by an auditory display. The software synthesis program SuperCollider is used to create a sonification model.

The sonification relies on the auditory system's suitability for following multiple data streams. The data set which represents the interbeat interval times is used to generate a variety of data vectors created from statistical and nonlinear dynamical analyses. Each vector is treated as though it were a track in a multi-track music recording. They all exist as separate list variables in the SuperCollider synthesis program, and a graphical user interface allows the relative volume levels of each to be adjusted during playback. The following parameters are sonified:

- The interbeat interval series
- Larger intervals, those which differ from the last time interval by more than 50 ms
- A sliding window representing the standard deviation of 300 beats
- A sliding window representing the mean of 15 beats, with fine resolution
- A sliding window representing the mean of 5 beats, with coarse resolution

Each data point is mapped to sound parameters such as pitch, timbre and tremolo rate. The relationship of the various parameters to each other may be compared by making adjustments to the GUI sliders to create an optimal "mix."

The number of data points sonified per second may be adjusted during playback.

The elapsed time represented by the current data point is displayed. Users may pause playback and reset the starting time to any desired point in order to focus on particular areas of the data set.

This sonification model has been shown to reflect in an unambiguous fashion the heart rate oscillations associated with obstructive sleep apnea via the two sonifications of a running mean. These oscillations are often difficult to detect in visual representations.

The model shows potential for continued research due to its open-ended nature. Analyses of heart rate variability often attempt to reduce the complexity of interval set by signal processing operations which focus on a finite number of characteristics, a process which must necessarily remove other elements from it. An auditory display of this nature may keep the original data set intact while including any number of abstractions of it. Data sets can easily be added or removed to the SuperCollider code, allowing a potentially unlimited number of processing operations to be sonified simultaneously.