Listening to the Mind Listening - A Sonification/Composition

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ABSTRACT

The following explains what mappings have been chosen for a sonification of several data channels from set containing a recording of the neural activity of a person listening to a piece of music. This piece, and also the sonification, is exactly 300 seconds long. My aim is to provide a sonification/composition that can be created in (near) real-time and takes its title literally. This is done by loading the data into a software program - Artwonk by John Dunn - and performing all mappings in real-time. The results are, again in real-time, sent to several software samplers that 'play' the music. Software samplers were chosen because of their low CPU cycle consumption. If the number of sonification data streams is low (3 to 5) near real-time sonification is certainly possible.

REDUCTION

The first thing that was done was that the amount of data was reduced by a factor of 10. The original data format was sampled at 500Hz, which is a sample every 2 milliseconds. This is too fast a rate to be useful for music if you want to keep the music in sync with the original EEG trace. So the data is reduced by averaging every 10 samples in the original for 1 sample in the data here. Thus, instead of 150,000 samples, there are 15,000 samples per channel, which represents one sample every 20 milliseconds and just happens to be the default ArtWonk main loop tick interval. Not only the raw data values are used, but also the deltas. The deltas were derived simply by subtracting datum n-1 from datum n for each sample in the array, starting with the first element. All data reduction was performed by John Dunn, the developer of ArtWonk. In my sonification/composition both original data and delta's are used.

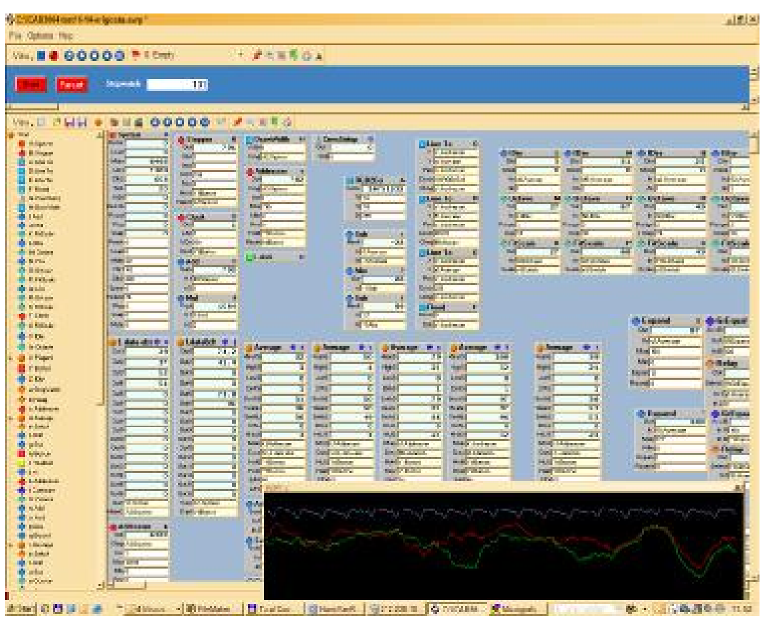

Figure 1. Screenshot of ArtWonk. The modular structure and the real time capabilities enable real-time adjustments of data mappings. The actual Listening to the Mind Listening composition is shown running here. There are separate modules for data import, data reduction, data mapping and sending out the resulting MIDI-data.

1.1. Contraints

Constraints for the sonifications:

- Data-driven. Sonification is the mapping of data into sounds for some purpose. The sonification should be the result of an explicit mapping from the supplied data into sounds.

- Time is the binding factor. The timeline of the data must map directly to the timeline of the sonification.

- Reproducibility. The mapping of the data into sound must be described in a manner than can be reproduced by others. Mappings should be described explicitly. Different mappings will enable different perceptions of information in the data. The experiment should lay a foundation for scientific and aesthetic observations and ongoing development by the research community.

1.2. Data driven

All data streams were loaded in ArtWonk and 'played' so the program could read all data (from arrays). The first step was to get the range of the raw data and the delta into a workable range. The next step was to get rid of the data peaks and valleys by further averaging the data, by taking both a sample of 50 and of 1000 values and calculating the mean, the highest value and the lowest value of these samples. These values were updated each time a new value arrived from the arrays at an interval of 20 milliseconds. The amounts of 50 and 1000 values – corresponding to 1 second and 20 seconds of data - were established by experiment and are in my view a good balance between musical and sonification considerations.

ArtWonk works with MIDI-values. This means that all subsequent mapping was done to achieve a range of 0-127. All values calculated were normalized to this 0-127 range. Because of the hardware constraints I have chosen to sonificate only three data streams: channel 36 ECG Heart Rate, channel 16 Central Parietal Left and ch18 Central Parietal Right. The difference between channel 11 Temporal Left (above ear) and channel 15 Temporal Right (above ear) was used for stereo positioning of channel 16 and 18.

Since the sonifications need to be musically satisfying for a general audience, I have chosen well known sounds: an acoustic bass for channel 36, and a grand piano for channel 16 and 18.

The pitch of all instruments is based on the highest value within the small averaging window (50 samples), the loudness is derived from the mean value of the large averaging window (1000 samples). Also higher (pitch) values will lead to transposition - 2, 4, 5, or 7 half steps, depending on the value. The switching values – which determine when to transpose - are chosen on musical considerations.

If the pitch values descend or remain the same, a pentatonic scale mapping is used, ascending values are mapped to fifths - or on minor triads if the data were ascending. The loudness of the instruments is derived from the mean value of the large averaging window. Next, these values were further reduced to two or more octaves to adapt tot the musical range of the used instruments and sent to the software sampler.

The rhythm is determined by the *rate of change* of the pitch values. If a new value is the same as the previous one, the note is held until a different value arrives. To make things musically an rhythmically more interesting, when loudness values of channel 16 (piano left) are *above* a certain threshold and loudness values of channel 18 (piano right) are *below* a certain threshold, the sound is abruptly cut off.

From a sonification perspective this means that channel 16 does not sound when the values are very large, and channel 18 does not sound when values are very low. Since both channels are based on delta values this means that the difference between subsequent values - based on the small averaging window - are very large (no sound channel 16) of very small (no sound channel 18).

1.3. Time

Because of the very heavy CPU load of the calculations and data mappings, the clock in ArtWonk lost some seconds. In order to compensate for these errors, the resulting WAV-files were (negatively) time stretched to 300 seconds. If ArtWonk runs on a fast, dedicated PC, this does not happen.

1.4 Reproducibility

All mapping can be reproduced. Upon request I can provide the ArtWonk-patch used for this sonification (no documentation yet). Very important is that this program allows the composer/sonificator to change most mappings instantly – *i.e. during the playing of the music* - either on musical grounds or on sonification grounds.

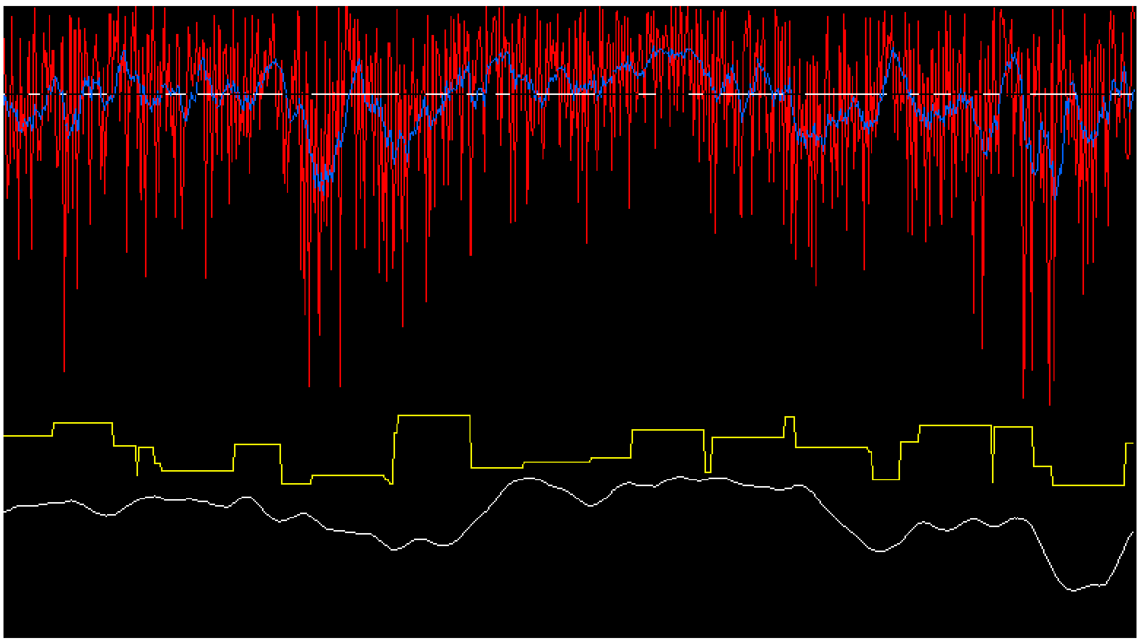

Figure 2. *Screenshot of data mapping with ArtWonk. This software can also be used for real-time visualization. The yellow line represents the mapped data for the pitch, the white line represents the loudness (average for 1000 values), the red line represents the original data, the blue line represents the average for 50 samples and the dashed line indicates if the average for 1000 samples ascends or descends (or remains the same).*

CONCLUSIONS

The sonification of data in (near) real-time is feasible if fast PC's are used. Feeding of EEG data from sensor electrodes will require a hardware interface and support by the software. The challenge however is to reduce the amount of data and, of course, the selection of a suitable mapping. In principle all kinds of data are suitable for musical mapping - not just well known mathematical data sets (e.g. fractals) - provided they exhibit some kind of pattern.

REFERENCES

1 ArtWonk - computer program by John Dunn (www.algoart.com)