Audio Engineering Society

Convention Paper

Presented at the 128th Convention

2010 May 22–25 London, UK

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A low-end device to convert EEG waves to music

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ABSTRACT

This research provides a simple and portable system that is able to generate MIDI output based data collected through an EEG collecting device. The uses of such a device are beneficial in many ways, where the therapeutic effects of listening to the music created by the brain waves documents many cases of treating health problems.

The approach is influenced by the interface described in the article “Brain-Computer music interface for composition and performance” by Eduardo Reck Miranda, where different frequency bands trigger corresponding piano notes through, and the complexity of the signal represents the tempo of the sound. The correspondence of the sound and the notes has been established through experimental work, where data of participants of a test group where gathered and analyzed, putting intervals for brain frequencies for different notes. The study is an active contribution to the field of the neurofeedback, by providing criteria tools for assessment.

1. INTRODUCTION

The belief that electroencephalography (EEG) can be used to generate sounds is not new. It dates back to early seventies. since when researches have tried to construct devices which can render these signals into sound. One of the most challenging difficulties is how to interpret EEG waves. Most importantly, scholars attempt to correlate them with the quantitative characteristics of music: namely, pitch, duration, pulse, timbre. the key task which is at the core of this paper is to make the most accurate representation of brainwaves which has yet to be performed. Numerous attempts have been made, but none of the techniques or the technologies found in related literature can be regarded as fully reliable.
Another point which needed in-depth examination , was the construction of technologies that can adequately capture EEG waves (Browse et al,3). The MIDI protocol has already been adopted by a several neuroscientists in order to monitor brain waves in real time (Hofstadter, 10).The sophistication of conversion software has enabled researchers to better use EEG signals in order to control MIDI (Zhang & Miranda, 3) in this previous work the positioning and number of sensing electrodes was also of great concern to the researchers as they needed to ascertain which parts of brain were directly responsible for creating melody. In this study, we needed to alternate several variants of positioning of which three (3) principal examples were the following :

- **Power spectrum (Filatriau)**
- **Event-related potential (Hjorth)**
- **Spectral centroid (Miranda & Boskamp)**

Under some circumstances all of these could be used quite efficiently. so, we tested them in connection with MIDI.

1.1. EEG WAVES AND SOUND WAVES

We know that “Sound is a regular mechanical vibration that travels through matter as a waveform” which exhibits all characteristics of longitudinal waves. (Kurtus).Sound waves with specific characteristics can be viewed as music. Alterations of ordinary sound in tone, note, time durations etc. create melody or music. The words of N’Diaye “a distributed network of brain areas has been repeatedly evidenced in timing tasks” identify musical touch of brain waves and activities. (N’Diaye, Garnero and Pouthas). Each state of brain is represented by certain waves called brain waves of which Gamma, Beta, Alpha, Theta and Delta are the recognized brain waves. Gamma waves (30 to 70 Hz) are produced while “processing of various attended stimuli…. From an EEG point of view, they will be present mostly while a subject is awake, but they will always be supported by other waves in the beta, alpha, theta, or delta ranges.” (Instant meditation: The Concept). Usual considerations are given to main brain waves excluding supporting gamma waves. “Brainwave activity tends to fall into four groups: beta, alpha, theta and delta. These categories are associated with the rapidity of oscillation (frequency) of brainwaves.” (Brainwaves).

It may be asked why usage of sound waves itself are adopted, rather than light or visual rays. This can be resolved by understanding that EEG signals can be easily represented by sound waves due to similarity of both in many of their characteristics. The selection of sound waves instead of light or visual rays is due to the properties of light itself. “Light is composed of transverse waves in an electromagnetic field....The denser the medium, the greater the speed of sound. The opposite is true of light.... Sound travels through all substances, but light cannot pass through opaque materials.” (Comparison of Light Waves with Sound Waves). The stated properties of light makes it inappropriate to be compared with EEG signals which are more alike sound waves.

1.2 SONIFICATION OF NEURAL SIGNALS

The sonification of EEG is of great value to the developers of musical applications: weather technologies or software solutions. On the other hand, this study recognized the importance of looking at this subject from a theoretical point of view as it helped in choosing the best methods of measuring, analyzing and converting brainwaves.
There are various distinct processes involved in converting neural signals to sound signals or sonification of neural signals. “Analyzing multichannel EEG signals using sounds seems a natural method: using a sonification of EEG signals.... perceive simultaneously every channel, and analyze more tractably the time dynamics of the signals – hoping to gain new insights about the brain signals.” (Vialatte and Cichocki). The sonification of neural signals is done in various steps having separate sets of procedures. “This process consisted of the following stages:

1. **Data acquisition**
2. **Data pre-processing:**
3. **Intermediate representation (the creation of visual and sonic map);**
4. **Visualization and sonification (Brouse et al, 9).**

1.3 BRAIN STRUCTURE AND MUSIC

It was important to identify the part of brain responsible for creating music. The two hemispheres make up major portion of brain , the right hemisphere is associated with creativity and the left hemisphere is associated with logic abilities (Brain Structures and Their Functions). The functions of right and left hemispheres make it clear that both are involved while the brain creates music. "Accepted neurological theories suggest that the right hemisphere deals with special elements like pitch whereas the left is responsible for the structure and progress of the melody
(Heslet, 2)." Studies of relations between neural regions and music (Levetin, 2006) illustrate the involvement of both hemispheres in creating music.

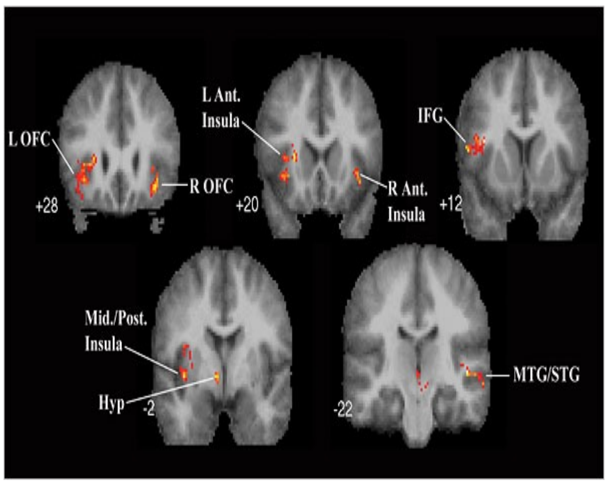

Figure 1.0 (Levetin ,2006)

"Images from an experiment to locate the neural regions of the brain involved in listening to music. Dr Levitin scanned the brains of 13 people as they listened to scrambled and unscrambled versions of a tune." (Levetin , 2006)

Several studies have sought out the points on the brain linked to meditation or music. This research has shown the scope of meditating music for neurological treatment. "Activity in the left prefrontal cortex (the seat of positive emotions such as happiness) swamped activity in the right prefrontal (site of negative emotions and anxiety), something never before seen from purely mental activity." (Mediation Alters Brain Structures).

The linking of brain structuring to meditational music experienced is a realistic success for neurology.

2. BRAIN WAVES CONVERSION

A number of methods are available to be employed in analysing the various factors involved in transforming brain waves to music. Power spectrum analysis (PSA) and Discrete Fourier Transform (DFT) techniques are suitable in our context. "The Fourier Transform of the Auto correlation Function is the Power Spectrum." (Nyack). Power spectrum is used in analysing various images which finds application in this investigation as well. The first step in PSA is to Fourier transform the image I(**x, y**) and calculates the square modulus of the FT to generate the power spectrum, **p (u, v).**

p(u,v) = |FT[I(x, y)]|2 (Power Spectral Analysis).

In order for us to obtain the active PSA , the FT array is rearranged according to frequencies in a way "that the zero frequency is in the centre of the array, the 1st quadrant is in the upper right, the second in the upper left, etc." (Power Spectral Analysis).

The resulting array was later converted to get values from 1.0 to 10.0 whose logarithm to base 10 is obtained. The array obtained was then used to obtain the required equivalent; here brain waves underwent power spectrum analysis to get music equivalent for them.

Discrete Fourier Transform (DFT) is another procedure carried out. "The Discrete Fourier Transform (DFT) allows the computation of spectra from discrete-time data... in discrete-time we can exactly calculate spectra." (Johnson). This definition itself explains the relevance of this method in our analysis of brain waves. Accurate computation is significant for conversion of brain waves to music waves so that least redundancies result.

2.1. LOW-END DATA COLLECTION AND ANALYSIS

The method adopted for data collection can be seen through the transformation of the EEG data, which was collected by an EEG collecting device as raw data. The approach is influenced by the interface described in the article Brain-Computer music interface for composition and performance by Eduardo Reck Miranda, where different frequency bands trigger corresponding responses to the recording device (Hofstadter, 2009)

Installation of an EEG unit poses many restrictions like size and cost , which led us to adopt the usage of a device named pendant EEG. "Pendant-EEG is a lightweight 2 channel EEG unit that can be clipped to your clothing and connects to your computer via a wireless receiver." (Pendant-EEG).

The communication essential for the application is given through wireless technique with efficiency by this. Our application can be relied with confidence on pendant EEG as "it can reliably process signals from 0.1 to 56 Hz." (Pendant-EEG).

3. SYSTEM DESIGN

The system used in the current project is built on the basis of the LORETA algorithm discussed about by Filatriau et al. (2007, p. 2). In more detail, the system design includes three major stages, i. e. EEG collection, digital signal processing, and MIDI representation. Graphically, the system design progress is identified in figure 2.0

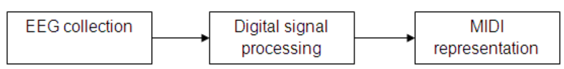

Figure 2.0

This system design permits collection of the EEG waves of the participants' brains with the help of electrodes placed on their both hemispheres. Next, the data collected is processed with the help of the LORETA algorithm (Filatriau et al., 2007, p. 2), and after this the system produces MIDI files on the basis of analogies between the qualities of EEG waves and specific musical notes.

As seen from the above statement (Filatriau et al., 2007, p. 2)., the LORETA algorithm plays a crucial role in the operation of the system design This algorithm is based on four major criteria defined and calculated as first, it is necessary to measure the potential of EEG wave occurrence, **Φ.** Second, the value of the sources producing those EEG waves, **φ,** is measured. The third and the fourth criteria that help in estimating the second point are the lead field matrix, **G**, and the rate of additional noise, **ŋ** (Filatriau et al., 2007, p. 2):

$$\Phi = G\,\varphi + \eta$$

At the same time, Ito et al. (2006, p. 1153) propose a slightly different formula that includes the role of mental change in sound stimulation, **S**, and the additional noise, **N**, for the calculation of **Y**, the time series data:

$$Y = S + N$$

In any case, both formulae require additional calculations, and Filatriau et al. (2007, p. 2) provide rationale for them, arguing that the bayesian formalism fits the goal of defining the value of the sources producing those EEG waves from the above formula. So, the design system discussed here uses the following formula to obtain the final data that are later sent to the sound synthesis module (Filatriau et al., 2007, p. 2)

$$P(\varphi/\Phi) = P(\Phi/\varphi)P(\varphi) / P(\Phi)$$

The data obtained through the above formula are ready for processing with the help of the LORETA algorithm that includes four stages:

1. **Sending the data to the sound synthesis module;**
2. **Associating the brain zones with cognition, visualization, and movements;**
3. **Creation of dipoles from the calculated data;**
4. **Computing the dipoles and using them as features for creating the respective MIDI files (Filatriau et al., 2007, p. 2).**

Thus, the use of the LORETA algorithm is the basis on which the performance of the discussed system design is founded and the scheme described in figure 2.1 becomes possible with the use of this cheaper technology :

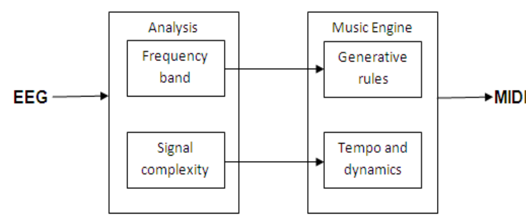

Figure 2.1(Filatriau et al., 2007)

At this point, the system's design performance follows this scheme and uses the LORETA algorithm to enable the researchers to convert the EEG waves into MIDI music files.

4. CONCLUSION

This study contributes to the field of neurofeedback, by providing criteria tools for assessment. The methods of notes assignment through average intervals of waves of bandwidth where tested to establish the similarity between the waves and notes in different groups. Hypothetically, this study significantly contributes to the knowledge of electroencephalography waves and their musical representation.

The system can be utilized for the development of affordable Brain Computer Interaction (BCI) systems. Furthermore, the results of the research are of great use for musical applications. Translation of EEG waves into sounds has grown into one of the most promising and challenging areas within neuroscience.

A great number of experiments have already been conducted in order to investigate the use of EEG signals to generate music . Of particular relevance is the creation of an experiment, performed by a group of scientists, headed by Filatriau, of an EED- driven audio-visual texture synthesizer (Filatriau et al, 3)which gave an opportunity to present these waves graphically and then to convert them into music. The authors propose that the intensity of the sounds is controlled by the level of energy in the alpha, beta and theta frequency bands (Filatriau et al, 3). The findings demonstrates that such experiments are feasible and should be taken into future considerations while developing conversion software

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