Insight2OSC: using the brain and the body as a musical instrument with the Emotiv Insight

Constanza Levicán, Andrés Aparicio, Vernon Belaunde, Rodrigo F. Cádiz
Center for Research in Audio Technologies
Music Institute
Pontificia Universidad Católica de Chile
Santiago, Chile
{cglevican,aaparicio,vabelaunde,rcadiz}@uc.cl

ABSTRACT

Brain computer interfaces are being widely adopted for music creation and interpretation, and they are becoming a truly new category of musical instruments. Indeed, Miranda has coined the term Brain-computer Musical Interface (BCMI) to refer to this category. There are no "plug-n-play" solutions for a BCMI, these kinds of tools usually require the setup and implementation of particular software configurations, customized for each EEG device. The Emotiv Insight is a low-cost EEG apparatus that outputs several kinds of data, such as EEG rhythms or facial expressions, from the user's brain activity. We have developed a BCMI, in the form of a freely available middle-ware, using the Emotiv Insight for EEG input and signal processing. The obtained data, via blue-tooth is broad-casted over the network formatted for the OSC protocol. Using this software, we tested the device's adequacy as a BCMI by using the provided data in order to control different sound synthesis algorithms in MaxMSP. We conclude that the Emotiv Insight is an interesting choice for a BCMI due to its low-cost and ease of use, but we also question its reliability and robustness.
—

Author Keywords

BCI, BCMI, EEG, Emotiv Insight

ACM Classification

H.5.5 [Information Interfaces and Presentation] Sound and Music Computing.

1. INTRODUCTION

A brain-computer interface (BCI) is a physiological computing system, specialized and designed to operate based on brain activity [7]. Hans Berger was the first person who measured waves from the brain in 1924, using a EEG device [11]. Neural activity often possesses a repetitive rhythmic quality, and these rhythms are classified according to their fundamental frequencies and are denoted as alpha, beta, theta or delta waves [15].
The fact that a machine can read signals from the brain has boosted the imaginations of musicians, engineers, scientists, artists and other enthusiasts, and EEG has made its way into applications in several realms, including music [11]. Many musicians and researchers dream with a day when musical ideas could be transmitted by simply making musical thought audible, an ideal performance without any physical limitations, where the performer plays with the expressiveness imagined in his mind [8]. In other words, musicians want to transform a BCI system into a musical instrument. In 1949, Raymond Scott wrote: "Perhaps within the next hundred years, science will perfect a process of thought transference from composer to listener. The composer will sit alone on the concert stage and merely think his idealized conception of his music. Instead of recordings of actual music sound, recordings will carry the brainwaves of the composer directly to the mind of the listener" [6]. Now, nearly a century after Berger's discovery, these dreams are becoming a reality [16].

NIME'17, May 15-19, 2017, Aalborg University Copenhagen, Denmark.

1.1 BCMI

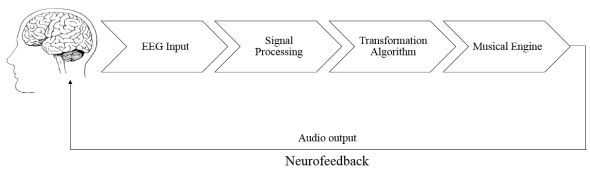

Figure 1: The schematics of a BCMI system. Adapted from [12, p.225].

A BCMI system is a BCI which returns a musical output. Figure 1 represents the steps of a BCMI system as described by Miranda [12, p. 227]. This systems contains the following stages:

1. EEG Input: EEG data recordings from the scalp.
2. Signal processing: amplification, analysis and classification of the data.
3. Transformation Algorithm: transforms the non-musical information into musical parameters.
4. Musical Engine: the system where musical parameters are turn into music.
5. Audio/Visual Stimuli (optional): it provides neuro-feedback to the user.

Miranda clearly identifies three separate ways in which such systems can be used for musical purposes: "When looking back on research into music and brainwaves, we can separate systems into three categories: ones for EEG sonification, ones for EEG musification and ones for BCI control. EEG sonification is the translation of EEG information into sound, for non-musical and predominantly medical purposes. EEG musification is the mapping of EEG information to musical parameters; however, the EEG data are arbitrary and when possible can offer only loose forms of control. BCI control is inherent in systems where direct cognitive real-time control of music is achievable." [12, p. 227]
Most of the attempts to use BCI for musical purposes reported by the literature sonify EEG signals directly [15] [17] [4] [10], but others have developed other approaches, such as the rendering of musical chords with organic nuances [8], real-time notation [3] [2], networked musical performances [1], and the study of the differ-

ences between music imagery an music perception [13].

2. EMOTIV INSIGHT

The Emotiv Insight is a portable EEG which provides a wireless connectivity with computers and smartphones. It has a free software tool called Emotiv Xavier Control Panel compatible with Windows, OSC, Linux, Android and iOS. This program offers a brain-computer interface which detects emotional and mental states and also facial expressions in real-time. However, there is no access to the raw data collected by the device through this tool. Nonetheless, Emotiv provides a SDK with several examples that can be used to obtain information from the equipment for different purposes.
The headset has seven electrodes: two electrodes for the ground and noise reduction and five for scalp data measuring. According to the 10-20 International system, the names of the electrodes that the Insight has are: AF3, AF4, T7, T8 and Pz, as they are placed in the frontal lobe (frontal cortex), temporal lobe (parietal-temporal lobe) and parietal lobe (parietal-occipital cortex).

Figure 2: Emotiv Insight: stealth black model. (Image obtained from http://www.emotiv.com) One of the most notable features if this headset is the usage of dry electrodes.

The Emotiv Insight has several features which make it an interesting candidate for a BCMI. Among them, we can list the following:

1. It has five channels of EEG data, more than others commecial devices.
2. It include two reference's electrodes for noise cancellation.
3. Each channel has a data transmission rate of 128 Hz.
4. It has dry electrodes that do not need further preparation of be wet with saline solutions.
5. It has a blue-tooth connection which allows receiving of the data directly on a computer free of cables
6. It uses an internal lithium battery with minimum 4 hours of duration.
7. It includes three inertial sensors: accelerometer, gyroscope and magnetometer.
8. It costs around USD 300 and it is relatively easy to acquire, directly from Emotiv's website [1].
9. Emotiv provides a free SDK on github with several examples for developers.
10. The SDK allows access for EEG rhythms, facial expressions and inertial sensors.

Despite these nice features, we have found that the device has some problems that can impair a BCMI system and cause a degraded performance when compared to other similar tools. These disadvantages are:

1. The channel connections are unstable and every time that a disconnection happens the device sends wrong data from the electrodes.
2. The headset has a standard size and it does not work well with all people. Every user has a different head size and the apparatus did not fit correctly for all the members of our team.
3. The appliance presents "pop-up" artifacts. These are errors that occur when the electrode misses the contact with the scalp and suddenly sends incorrect measurements [14].

All these problems manifested in all of the three headsets we own.

[1] www.emotiv.com

3. INSIGHT2OSC

We developed *Insight2OSC*, a free middle-ware [2] that receives data from the Emotiv Insight device in real-time using his blue-tooth connection and sends it through the network using the OSC protocol. Insight2OSC is based on some of the examples that are provided by Emotiv's SDK. Not all of these examples are written in the same programming language, and they send just one type of data (as discussed in section 3.1) in a sequential way. Besides the examples that we discuss in section 4, our software includes several advantages:

1. Modularity: all routines are contained in the same file, but they called separately.
2. Parallelism and speed: one of the main features of our tool is the efficiency and speed of data streaming. We used threads, with a high level of parallelism, allowing us to send all the data available in the Emotive Insight device concurrently.
3. Usability: our software runs on Windows or MacOS in standalone mode.
4. User experience: our middle-ware is user-friendly and very simple to use. Additionally, the software displays the connection's status of all electrodes using the color scheme detailed in table 1.
5. Anti "pop-up": in order to prevent considerable discontinuities in the data due to "pop-up" artifacts, the average band power of the electrodes is taken into consideration only when they have a good quality of connection with the skin.

When the software starts, it searches for an Emotiv Insight via blue-tooth or waits for a device to connect. Once connected, it will automatically start sending data to the IP and Port that it has by default, as figure 3 displays. The IP and port can be changed directly from the main window as shown in figures 4 and 5.

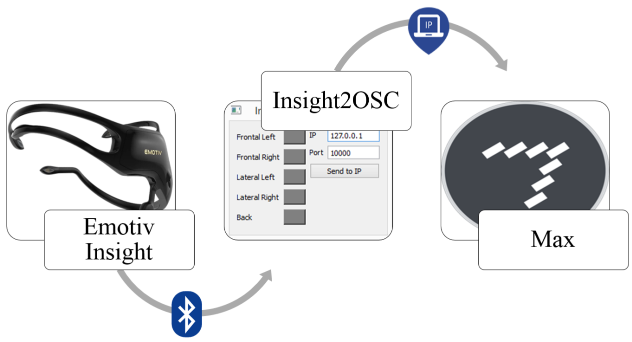

Figure 3: The flow of data in Insight2OSC. Data obtained via blue-tooth is sent through the network using the OSC protocol, to an audio software such as MaxMSP.

The Insight2OSC has two versions: Windows (shown in figure 4) and OSX (shown in figure 5).

Color	Quality of connection
	None
	Bad
	Poor
	Good

Table 1: Color scheme for the connection quality of the device electrodes.

[2] Available from https://github.com/rcadiz/Insight2OSC.git

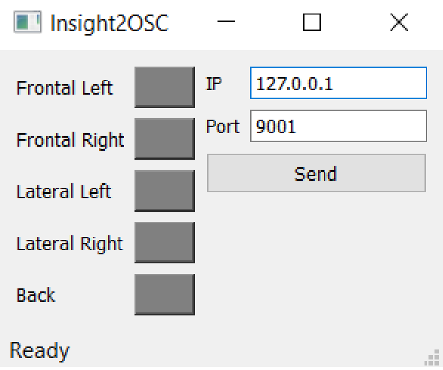

Figure 4: Insight2OSC main window for Windows. IP address and port can be changed and electrode status are displayed using a color scheme.

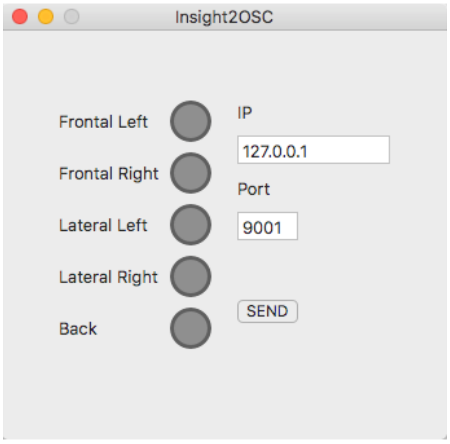

Figure 5: Insight2OSC main window for OSX. IP address and port can be changed and electrode status are displayed using a color scheme.

3.1 Data

Insight2OSC sends all available data from the Emotiv Insight, as follows:

1. Inertial sensors: the Emotiv Insight includes three inertial 3D sensors: gyroscope, accelerometer and magnetometer, therefore, it sends a list of 3 decimal numbers for each sensor (X, Y, Z)
2. Headset Status: a whole number for each headset measurement, including the percentage of battery (1-100), the signal level of the wireless connection (1-4), the time of connection (>1), the connection's status of all electrodes (1-5).
3. Average band power: a decimal number corresponding to the power of frequency bands: alpha, beta low, beta high and gamma, for each electrode.
4. Mental states: a decimal number that represents the percentage of stress, relaxation, engagement, interest and focus of the person.
5. Facial expressions: a 0 or 1 if the person had recently blinked or winked, a decimal number representing the percentage of surprise, furrow, smile and clench of the face expressions.

Figure 6 shows the labeling scheme we use for all the data that is obtained from the Insight2OSC device according to the OSC protocol syntax.

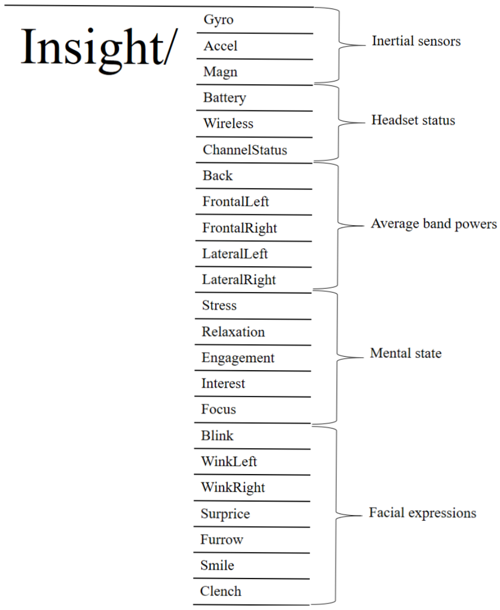

Figure 6: Emotiv Insight data and its OSC syntax.

4. APPLICATIONS

We also developed four musical applications using the widely used sound processing environment MaxMSP[3]. All the described applications create sound based on the data described in section 3.1. These applications can be seen in the accompanying video abstract.

4.1 Direct mapping of EEG rhythms

The electrical signals of the brain present several spontaneous oscillatory signals [9]. For this reason, brain activity could be classified depending on different frequency bands called EEG rhythms or brainwaves. *Delta* rhythm (0-4 Hz) is not present in normal and waking adult, *theta* rhythm (4-7 Hz) is low in waking adults [14]. The most used rhythms on BCI system are *alpha* (8-13 Hz) and *beta* (14-20 Hz) [9]. *Alpha* is higher in a relaxed situation [14]. In particular, the *alpha* rhythm is higher when a person is in a waking, relaxed or eye-closed state [14] [5] and it is lower when the subject is in an alert state or receiving visual stimuli [5]. *beta* rhythm is present when a person moves because is part of the sensorimotor rhythms as well as the *gamma* rhythm (30 and more Hz) [16] [9]. It is very hard to visualize the raw signal due to the oscillations between 0 Hz and 100 Hz that it contains. One of the ways to study the signal is with a frequency domain analysis. Therefore, in any BCI it is crucial to have all the frequency bands power.
The sonification of EEG rhythms is a useful method to analyze the electrodes raw signal due to the fact that it can create very easily distinguishable sounds from each other.
Additionally, it appears that the musification of EEG rhythms is an interesting approach for live performances. Perhaps the most famous one is the 1976 performance by Alvin Lucier, who mapped directly the power of his *alpha* rhythm in a live performance called *Music for Solo Performer* [12]. After that, several artists have mapped their EEG activity in real-time on their performances.
In the attached video abstract, we show the usage of the power of the *alpha* rhythm when mapped to control the overall dynamic of a sound. It is possible to appreciate a decreasing of the total volume when going into a more alerted state.

4.2 Body sensors

The Emotiv Insight provides the measurements of three inertial sensors: gyroscope, accelerometer and magnetometer. These sen-

[3]http://www.cycling74.com

sors give information about all types of head movements. The interesting part is that sensor measurements gives really accurate values, with a very small margin of error. It allow us to notice the difference between fast or slow movements, or even detect a turning head movement or an straight one. These values are completely manipulable by the user and have many musical applications.
In the video abstract, we propose a musification of the 3-axis gyroscope, used to control the pitch, timbre and dynamics of a sound. As gyroscope were used, there is no sound when the user is standing still.

4.3 Neuroscience-based input

A user-orientated BCMIs is an interface created to deduce the user's intentions [12]. They are based on advanced neuroscience knowledge and digital signal processing. In this case, we propose a user-orientated BCMI system using the power of its beta rhythm.
Sensorimotor rhythms (SVMs) are oscillations of the electric field which could be recorded by the EEG, and include *mu* (8-12 Hz), *beta* (18-20 Hz) and *gamma* (30-200 Hz) [16] [9]. The SVM are related to real and imaginary movements [16]. When a person moves some SVMs increase and others decrease. The first process is called event-related synchronization (ERS) and the second is called event-related desynchronization (ERD) [16].
For example, when the user moves there is an increase in the power of the *beta* rhythm as a result of ERS. In consequence, a peak occurs one second after the onset of the movement. In the video abstract, we identify the peak of a beta rhythm in order to control the pitch and timbre of different sounds.

4.4 Facial expressions

Facial expressions produce artifacts in the EEG signals [14]. In consequence, BCI systems should be implemented with complex digital signal processing algorithms in order to eliminate them. Nevertheless, it is not always necessary to eliminate them. We think that using these artifacts might be something interesting for musical reasons. The Emotiv Insight provides facial expressions, which are estimated using internal signal processing algorithms. The provided facial expressions are: blink, wink left, wink right, surprise, furrow, smile and clench.
In the video abstract, we propose the musification of facial expression in order to alter some aspects of the sound. In particular, we use smiles to increase the tempo of a steady rhythm.

5. CONCLUSIONS

We have developed a simple tool that allows accessing all available data provided by the Emotiv Insight device, and routing it to any OSC-enabled audio software such as MaxMSP. This data includes power of EEG rhythms, facial expressions, mental states and inertial sensors. Our software has two versions: Windows and OSX.
We want to conceive the Emotiv Insight appliance as a musical instrument. Our motivation is to allow musicians to transform this data into musical parameters in order to use it for musification and build their BCMI. In addition, our BCMI allows for any user to close the neuro-feedback loop (figure 1) by training himself using our musification.
As the Emotiv Insight provides a considerable amount of data with a great sample-rate, this middle-ware provides a great number of possibilities for audio-visual performances in real-time. We believe that Emotiv Insight device is an interesting choice for BCMI but we also question its reliability and robustness.
To strengthen our appreciation, we present four musical applications based on several types of data: the information from the inertial sensors, facial expressions, direct mapping of EEG rhythms and the detection of the user's body movement via peaks in the power of the *beta* rhythm.

6. ACKNOWLEDGEMENTS

This research was partially funded by Fondecyt Grant #1161328, and Dirección de Artes y Cultura, Vicerrectoría de Investigación, Pontificia Universidad Católica de Chile.

7. REFERENCES

[1] A. D. Brouse. *The Interharmonium: an investigation into networked musical applications and brainwaves*. PhD thesis, McGill University, 2004.

[2] R. F. Cádiz and P. de la Cuadra. Kara: a BCI approach to composition. In *Proceedings of the International Computer Music Conference and Sound Music Computing (ICMC|SMC)*, pages 350–354, Athens, Greece, 2014.

[3] J. Eaton and E. Miranda. Real-time notation using brainwave control. In *Sound and Music Computing Conference*, 2013.

[4] M. Elgendi, B. Rebsamen, A. Cichocki, F. Vialatte, and J. Dauwels. Real-time wireless sonification of brain signals. In *Advances in Cognitive Neurodynamics (III)*, pages 175–181. Springer, 2013.

[5] R. I. Goldman, J. M. Stern, J. Engel, and M. S. Cohen. Simultaneous EEG and fMRI of the alpha rhythm. *Neuroreport, physiology,Parietal Lobe,Parietal Lobe: physiology,Thalamus,Thalamus: physiology*, 13(18):2487–92, 2002.

[6] M. Grierson. Composing with brainwaves: minimal trial p300b recognition as an indication of subjective preference for the control of a musical instrument. In *Proceedings of International Computer Music Conference (ICMC '08)*, 2008.

[7] H. Gurkok and A. Nijholt. Affective brain-computer interfaces for arts. In *Affective Computing and Intelligent Interaction (ACII), 2013 Humaine Association Conference on*, pages 827–831. IEEE, 2013.

[8] T. Hamano, T. M. Rutkowski, H. Terasawa, K. Okanoya, and K. Furukawa. Generating an integrated musical expression with a brain–computer interface. In *Proceedings of the New Interfaces for Musical Expression Conference (NIME 2013)*, pages 49–54, 5 2013.

[9] B. He, S. Gao, H. Yuan, and J. R. Wolpaw. Brain Computer Interfaces. In B. He, editor, *Neural Engineering*, chapter 2, pages 87–152. Springer US, 2 edition, 2013.

[10] T. Hinterberger. Orchestral sonification of brain signals and its application to brain-computer interfaces and performing arts. In *Proceedings of the 2nd International Workshop on Interactive Sonification (ISon 2007). York, UK. Online*, 2007.

[11] E. R. Miranda. Brain-computer music interface for composition and performance. *International Journal on Disability and Human Development*, 5(2):119–126, 2006.

[12] E. R. Miranda. *Guide to Brain-Computer Music Interfacing*. Springer, 2014.

[13] F. Olthuis. EEG differences between music imagery and music perception. In *15th Twente Student Conference*, Enschede, The Netherlands, 6 2011.

[14] A. J. Rowan and E. Tolunsky. *Primer of EEG*. Butterworth Heinemann, 2003.

[15] A. Stella. *Auditory Display of Brain Oscillatory Activity with Electroencephalography*. PhD thesis, Universidad Pompeu Fabra, Barcelona, 2012.

[16] J. R. Wolpaw and E. W. Wolpaw. *Brain–computer interfaces: something new under the sun*, pages 3–12. Oxford University Press, New York, 2012.

[17] D. Wu, Y. Liu, and D.-Z. . Z. Yao. Listen to the brain in real time - the chengdu brainwave music. *Journal of Electronic Science and Technology of China*, 7(1), 3 2009.