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An Interactive Compositional Tool using the Electroencephalogram

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Abstract

This paper proposes an interactive approach to aid the compositional process using the brain-computer music interface (BCMI). In particular, the system developed in this paper focuses on creating an interactive compositional process inclusive to non-musicians and those with motor disabilities, in addition to providing a new method of composing. This paper references and compares two BCMI systems that have been developed for compositional purposes and draws upon these ideas to form the proposed system in this paper. Such system would aid the compositional process based on note velocity, chords and key changes.

1 Introduction

Imagine a world where we could create a melody in our head and have a computer compose it as we think. Unfortunately, this idea is rather far-fetched, and technology has a long way to go before this becomes a reality as opposed to merely an idea. However, technology such as the brain-computer music interface (BCMI) is the initial move towards such a technological development. The BCMI comes from a cross disciplinary field that combines methodologies from the field of Neuroscience and Computer Music. The BCMI branches from the brain-computer interface (BCI), a system that allows for communication or control of a computer using human brainwaves. During the 1920s, psychiatrist Hans Berger discovered the electroencephalogram (EEG), a method of recording brain signals [1]. This subsequently led to the discovery of the alpha and beta waves, two very prominent frequency waves in the human brain. While the EEG became a widely used tool within the medical domain, it had also made its way into applications such as virtual reality (VR), mouse control and musical control [2].

The idea of using brainwaves for musical purposes began in 1965, when composer Alvin Lucier used the EEG to amplify his alpha wave through a number of loudspeakers that were attached to a variety of percussion instruments, thus creating a musical recording [3]. Notably, this became known as the first musical piece to be composed using brain waves. Further to his work, composers such as David Rosenboom and Richard Teitelbaum began experimenting with the concept of using bio-signals such as the heart rate and breathing sounds to create an electronic texture composition [3]. Although the term brain-computer music interface (BCMI) was not coined until 2006 [1], it is widely accepted across the literature in this field that these experimental composers are the first pioneers of the BCMI.

More recently, this technology has been used as a communication medium for people with physical disabilities and people with limited or no muscle movement [2]. Miranda *et al* [2] developed a BCMI system that allowed a user who had motor disabilities to compose music by selecting the desired musical phrase on a computer screen. This allowed them the ability to compose music that they would otherwise have been unable to do.

In this paper I present a BCMI system that acts as an interactive compositional tool to be used by musicians, non-musicians and those with motor disabilities. This system is an updated version from a previously published article [4]. The proposed system will use the alpha and beta waves, retrieved from the user's EEG data, for the purpose of control over musical parameters within a pre-composed composition.

2 Musical composition with the BCMI

This A BCMI that is developed for the purpose of musical composition can achieve fascinating results. Current BCMI systems can allow for a user to change the structure of a piece or alter the musical tempo via their brainwaves. These changes can represent the user's current mood or emotion, or simply be an interactive way to altering pre-composed compositions.

There are numerous methods that can be used to measure the brain signals for music control, such as the electroencephalogram (EEG), magnetoencephalogram (MEG), and the functional magnetic resonance imaging (fMRI) to name a few. The EEG and MEG both have a very good temporal resolution, however the MEG provides a greater spatial resolution in comparison to the EEG. The temporal resolution, which is the speed at which the brainwaves are recording at, is important in a system for musical composition as it a sufficient temporal resolution will allow for adequate real time mapping of musical parameters. The fMRI has a poor temporal resolution, with 5-8 seconds being the time between two data points that can be distinguished, meaning it would be unsuitable for real-time mapping. For a system that focuses on musical composition, it is important to make this system as accessible as possible. The MEG and fMRI have equipment that is extremely bulky and can only be used in specialised laboratory conditions, whereas the EEG equipment is small, portable, and has no restrictions on being used outside of a laboratory-controlled environment.

Miranda *et al.,* [2] developed a BCMI system to be used by those with severe physical disabilities. This BCMI utilised the EEG and incorporated an eye-gazing technique; steady-state visual evoked potential (SSVEP). This technique requires icons to be displayed on a computer screen, with each icon flashing at different frequencies. Specifically, this system used four flashing icons that were correlating to the frequencies of the relative brainwaves that were being measured. Each icon represents a musical command that is fed back to the musical engine. To select one of the four icons, the user is required to simply gaze at the icon which increases the amplitude of the relative brainwave frequency. This technique allows for those with motor disabilities to be able to select icons using eye movement. However, using a technique such as the SSVEP would require knowledge and advanced computer programming skills, far beyond the scope for those who have had no training in this field. Essentially, the user of this system is only controlling the structure of the phrases as opposed to any compositional changes such as the dynamics or note values. In comparison to this system, Miranda and Soucaret's [5] BCMI system utilises the alpha and beta waves to control the volume of two tracks. The first track is an electric guitar solo, which increases in volume when the alpha wave becomes prominent, and reduces in volume when the beta wave became more prominent than the alpha. The second track is a piano solo that would increase in volume when the beta wave is prominent. While this system is only allowing for the user to have control over the volume, the level of control that this offer is intriguing. A user would be able to, with practice, train themselves to prompt their alpha and beta waves. Miranda and Soucaret [5] stated that the user was able to successfully gain control in a matter of minutes, providing accurate results. In addition to this, such system would be inclusive for those with motor disabilities. Both systems referenced here have provided the ability to change parameters of a pre-composed composition. The way forward is to develop a system that allows for multiple musical parameters to be controlled by the user and to create an interactive compositional tool.

3 Description of the proposed system

The proposed system expands on the work of Miranda's [5] BCMI system to include more musical parameters for the user to interact with a composition, whilst also taking inspiration from these authors [2] system in terms of making it accessible for those with motor disabilities. The musical parameters included in this system are note velocity, chord changes and key changes from major to minor. The user will be able to change these parameters in a pre-composed composition using their alpha and beta waves.

Technical Aspects of the System

The equipment used for this system was the g.tec g.Sahara dry electrode system. This system is made up of four parts, which are the g.GAMMAcap, g.SAHARA electrodes, g.SAHARAbox and the g.MOBIlab+. The g.MOBIlab+ is an analogue-todigital convertor sampling at a fixed rate of 256 Hz. The electrodes are positioned according to the international 10-20 electrode placement system. Hinterberger and Baier [6] state that the parietal and occipital region of the brain can give higher amplitudes in the alpha range. While this is true, Le Groux and Vershure [7] argue against using the occipital region due to the user's hair causing too much interference, whereas the frontal region can prove successful in measuring alpha waves.

A total of three electrodes are used and positioned at Fp1, Fp2 and FpZ, with the reference electrode clipped onto the ear. The raw EEG signals are received via Bluetooth from the g.MOBIlab+ and sent to OpenVibe, a program that provides a convenient interface between the EEG headset and the programming software. OpenVibe can be used to filter and process brain signals in real time, which allowed for the extraction of the alpha and beta frequencies from the raw EEG signal. The extraction was achieved using a band-pass filter. Although there is much controversy to the exact frequency band of both the alpha and beta wave, the majority of literature in this field uses between 8 Hz to 13 Hz for the alpha wave and 14 Hz to 30 Hz for the beta wave [8; 12]. Therefore, these frequency bands were used for the band-pass filter.

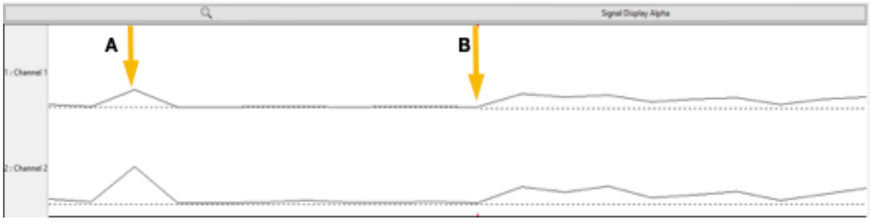

Fig. 1. Example of the alpha wave fluctuation.

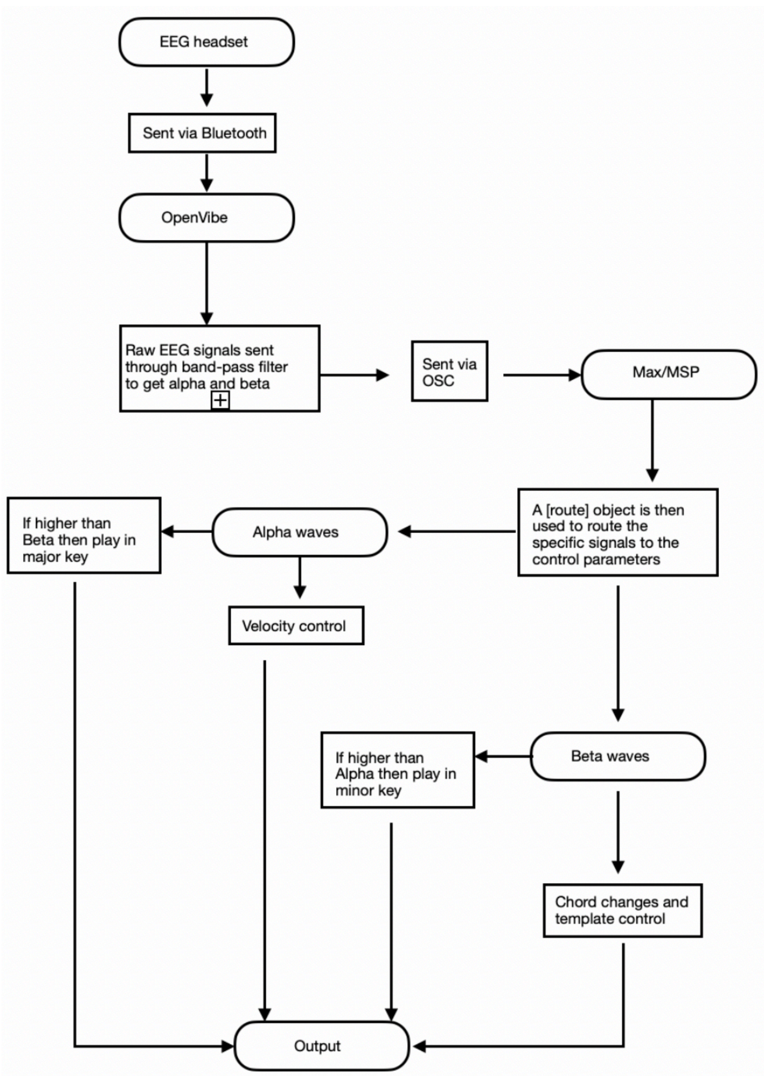

Fig. 2. Flowchart of the system set-up and how the system works.

The fluctuation of the alpha wave will be responsible for controlling note velocity of the composition (fig. 1). In the first half of figure 1, the user had their eyes open and was engaging their mind on a mental task. Here, the alpha wave is almost absent, with a peak in the wave at A when the user blinked. At B, the user closed their eyes and relaxed. We can instantly see the fluctuation of the alpha wave as it becomes more prominent and active when the eyes are closed. This will be incorporated into the system so when the user closes their eyes, the velocity will decrease. When the user opens their eyes, the velocity will increase.

The alpha and beta wave data was sent to the visual programming software Max/MSP via Open Sound Control (OSC). OSC is simply a protocol for communication over networks that allow data to be sent from an EEG headset to programming software. Max/MSP is the musical engine for this system, which was chosen due to the fact it does not adopt text-based coding, therefore making it suitable and less daunting for someone with little to no experience in programming. The incoming alpha and beta waves were monitored so the data could be scaled to the associated musical parameters. The amplitude of the alpha wave is responsible for controlling the velocity of the melody and the chords. The amplitude of the beta wave is responsible for controlling the velocity of the harmony, choosing the chords and the chord templates (how many milliseconds are between the notes of the chord). Both the alpha and beta wave controls whether the composition changes from major to minor. The flowchart in figure 2 shows the technological set-up of the system including the generative algorithms.

Compositional Aspects of the Composition

The pre-composed composition consists of 96 bars, which form three sections in the ternary form (A, B, A). The composition is formed of a main melody, harmony and chord accompaniment. Composed in Bb major, the user has the option to change the composition to the parallel minor – Bb minor – simply by opening their eyes and focusing on a mental task, prompting the beta wave to become prominent. To change the composition back to Bb major, the user will have to close their eyes and relax to prompt the alpha wave. The chords that are included in this composition are the tonic, dominant and leading note chords of the Bb major scale in root position, first inversion and second inversion. This provides enough choice so the chords will not become repetitive, but also keeps it simple enough for someone with no musical knowledge to be able to understand. In relation to the chords, the user will be able to control how they are played, i.e. the milliseconds between each note of the chord, from a pre-defined list that is scaled to the users beta wave. The user will be able to control the velocity of the notes in the main melody, harmony and the chords through their alpha wave. The velocity of each will be scaled appropriately in Max/MSP. For example, the velocity of the chords will not go as high as the velocity of the melody, as it is musically known that chords are used as an accompaniment to a melody and is therefore dynamically quieter. The three sections of this composition allow for the user to change the velocity of each section to provide contrast. The rhythmic phrase leading up to section B (fig.3) acts as an auditory parameter that the user will be able to recognise and subsequently prompt a contrasting velocity to the previous section.

Fig. 3. Excerpt from the pre-composed composition; characterised by the triplet and duplet aimed to give the feel that the music is slowing down, before reaching a flourish of semi-quavers leading on to the B section.

4 System testing and results

The system was tested on three participants, including the author, to determine how well they could control their alpha and beta waves and subsequently the musical parameters. The setup of the system took approximately 10 minutes. This included placing the headset onto the scalp, connecting it to OpenVibe and obtaining satisfactory contact between the electrodes and the scalp. The participants were required to sit still for the entirety of this test to avoid any interference from muscle movement that may cause inaccurate results. The lack of movement that is required to use this system makes it appropriate to be used by those with motor disabilities, as they will not need to use a keyboard or mouse to make any changes to the composition. Each participant was required to begin the test with their eyes closed and in a relaxed state to prompt their alpha wave. This should result in the composition playing back in the major key at a low velocity. Once the composition had played back, it would loop, and this is when the participants were instructed to open their eyes and focus on a mental task. This would result in the composition playing in a minor key with a high velocity. Each participant tested the system for 20 minutes.

Participant 1, the author, had knowledge of how this system operates and had previous practice with this system. The author was able to successfully control their alpha and beta waves and subsequently the musical parameters, providing an accurate result. Participant 2 had no previous experience with BCMI systems but had knowledge of musical compositions. While they were able to successfully prompt their alpha waves, they struggled to induce and maintain their beta waves. This resulted in the velocity changing from low to high very quickly. However, because the data is always representative of their biological state, this provided interesting but meaningful results. Participant 3 had no previous experience with BCMI systems or musical composition. They reported it difficult to maintain control of their alpha and beta waves, resulting in fluctuating velocities throughout playback.

While two out of three participants reported that they struggled to maintain control over their alpha and/or beta waves, the outcome of the musical composition still sounded pleasant due to the pre-composed composition. It has often been reported that the user of a BCMI will be able to control their brainwaves after some practice [5]. This has been proven with participant 1, who with practice managed to induce their alpha and beta waves at will.

5 Concluding remarks and future work

In this paper I presented a BCMI system that provided an exciting and interactive approach to composing music. This system draws upon the technological advances that have previously been developed and expands the possibilities that can be achieved with such technology. Future work will explore the potential of controlling all aspects of this system purely from the user's brainwaves, allowing them to play and stop during real-time playback. Further to this, the possibility of using this system in a performance setting will also be explored.

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