Brain Computer Interface, Visual Tracker and Artificial Intelligence for a Music Polyphony Generation System

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Abstract. In the Brain Computer Interface domain, studies on EEG represent a huge field of interest. Interactive systems that exploit low cost electroencephalographs to control machines are gaining momentum. Such technologies can be useful in the field of music and assisted composition. In this paper, a system that aims to generate four-part polyphonies is proposed. An artificial intelligence algorithm permits to generate polyphonies based on the N. Slonimsky's theory by elaborating data coming from a Leap Motion device, to detect user's hand movement, and a five-channel EEG signal detection device.

Keywords: EEG, Brain Computer Interface, Leap Motion, Slonimsky

1 Introduction

Fig. 1. Techniques for inserting notes within interval axes

A music composer continuously develops music models that represent her idea of music. Such models can be intended as musical materials useful in the construction of the final piece. Thus, composers explore multiple combinations of pitches, rhythmic profiles, dynamics, and all the other parameters that represent sound in general. In 1947, the composer N. Slonimsky published a treaty entitled "Thesaurus of Pattern and Melodic Scale" [1], in which he presented a technique for constructing melodic patterns based on dividing one or more octaves into equal parts. According to Slonimsky, the construction of melodic patterns can be made systematic by inserting notes below, within and above a musical interval-axis (see Fig.1). Once the type of interval division of the octave is chosen[1], notes can be inserted within (Interpolation), beyond (Ultrapolation) and below the division interval (Infrapolation). By combining these techniques

[1] In Fig 1, the octave between the C note under the pentagram and the C note in the second upper space has been chosen and is represented in the Principal Tones section.

for filling interval-axes, sinusoidal profiles of Infra-Interpolation, Infra-Ultrapolation and Infra-Inter-Ultrapolation are obtained.

In this research work, a technological tool is presented that exploits Artificial Intelligence algorithms, a Leap Motion controller [2], and a five-electrode Emotive headset [3] to support composers in exploring melodic profiles that represent the basis for composing new music pieces via the Slonimsky's Infra-Inter-Ultrapolation technique.

2 The polyphony generation system

The system architecture is schematized in **Fig. 2**. The *Pitch Profile Generator* module on the left side is based on an algorithm that transforms into note pitches the coordinates of the composers' fingers detected by the Leap Motion device. The result is a pitch profile, i.e. a sequence of notes without indications about their duration. The module on the right side is characterized by *FeedForward Net Classifier* that, with a Deep Network algorithm, analyzes the EEG signal coming from the five electrodes of the Emotiv headset worn by the composer and classifies her mental status as "focused" or "relaxed". Here, a mental status is intended a sequence of power spectrum values obtained from the EEG signal. The algorithm has been previously trained by the specific composer's mental status dataset. The *Polyphonic Structure Generator*: 1) receives the pitch profile, 2) multiplies it by four to have a draft polyphony, 3) according to the composer's mental state, gives a duration to the notes of the four pitch profiles, which are differentiated by means of a scramble method.

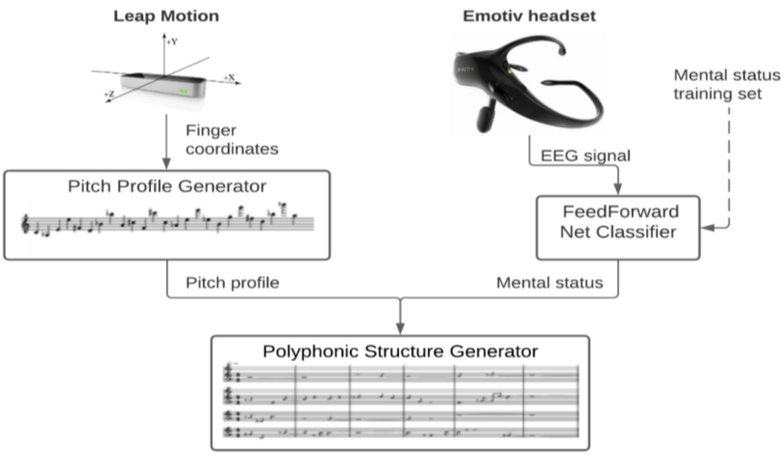

Fig. 2. System architecture

By means of the Cortex API SDK [4], the system derives a series of numerical values in the overall frequency 1-43 Hz, classified in different bands of the power spectrum of interest, i.e., Delta (0-4Hz), Theta (4-8Hz), Alpha (8-12Hz), Beta (12-35Hz) and Gamma (>35Hz). The Keras framework [5] is used to implement the Deep Network algorithm as shown in **Fig. 3**.

```
model = Sequential()
model.add(Dense(50, input_dim = X_train.shape[1], activation="relu"))
model.add(Dense(1, activation="sigmoid"))
model.compile(optimizer='sgd', loss='binary_crossentropy', metrics=['accuracy'])
model.summary()
model.fit(X_train, Y_train, epochs=100)
accuracy = model.evaluate(X_test, Y_test)
```

Fig. 3. Deep Network algorithm implemented in Keras with Python

Before using the system for composing, it has to be trained to the mental states of a specific composer, so that the underlying network can adapt to the bandwidth variation characteristics, which is a specific function of each user. Such a "calibration" has to be done once for each user. The composer wears the BCI headset and samples herself in two different mental states, i.e., focused and consciously relaxed. Focused mental status means a higher amplitude of high frequencies in the range 13-40 Hz, which corresponds to the Beta and Gamma frequency bands. Consciously relaxed means a greater activation of low frequencies and specifically the Alpha band between 8-13Hz.

If the mental status classified as Focus, the polyphony is generated with rhythmic figures such as quarter note, height notes, sixteenth notes, and their corresponding pauses. If, on the contrary, the mental status is Consciously relaxed, the polyphony generated has rhythmic values of short, whole notes, half notes, quarter notes and their corresponding pause values. In addition, each bandwidth value received in real-time from the BCI headset is used to assign a dynamic value to each generated note.

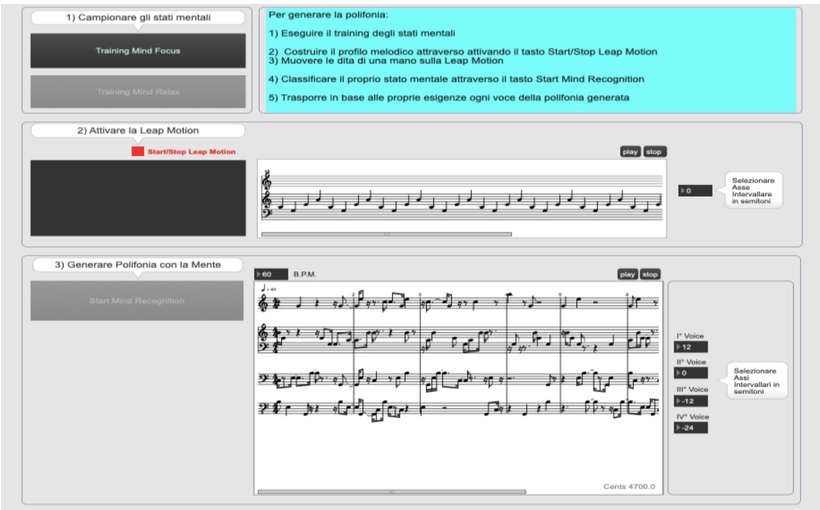

Fig. 4. User interface of the system.

Fig. 4 shows the system user interface, which is dived in three sections, as for the main phases of the polyphony composition process. Starting from the top, the first section is devoted to the two mental states training; a summary of the overall process is provided in the green box, which also acts as user guide. The second section is dedicated to generating the pitch profile using the Leap Motion visual tracker; a graph of finger positions is drawn in the black panel, while on the right the composer can see in real-time the pentagram with the sequence of generated notes. By means of the field on the right, the composer can possibly change the interval-axis. The third section shows how, in real-time, the pitch profile is transformed in the resulting polyphony according to the composer's EEG. A few further parameters can be set by using the other widgets in this section of the interface.

The generated polyphony can be saved in a format compatible with popular software tools, e.g. MAX/Msp [6], that the composer can use for refining it and transform in the final piece of music.

3 Conclusions

In this paper we presented an approach aimed at generating complex polyphonic structures related to the theoretical model of Slonimsky, useful for the composer who wants to optimize her compositional process. The polyphonic material obtained is deliberately not complete in a strict musical sense, because we want to leave to the composer the possibility to work and perfect it according to her artistic needs. The creative process is a process that involves different technical and emotional aspects and in this sense, the final goal is to demonstrate that the BCI, in our opinion, could be useful as a support, and not as a substitute, tool for the composer. The system can be evolved by expanding the compositional theoretical models, thus providing a wider support to the work of contemporary musicians/composers.

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