Brain Beats:Tempo extraction using EEG waves

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***Abstract*—The aim of this project is to extract the tempo[1] information from EEG(Electroencephalogram) recordings[2] using Music Information Retrieval(MIR) techniques which is originally used for extracting the tempo (speed of beats in music signals) from audio music signal. It is possible to track listeners attention to different speakers and music signals and even extract music or rhythmic information from EEG waves when the person is listening to music.**

***Keywords*—Music, tempo, EEG, beats, tempogram, signals, MIR**

I. Introduction

The tempo of the music recording from brain activity data(EEG) recorded during listening can be extracted using Music Information Retrieval Technique. It has been shown in recent research that oscillatory neural activity which is responsible for the brain waves is sensitive to accented tones with a rhythmic sequence pattern. Neural oscillations get synchronize to these rhythmic sequences and they increase with the strong tones(typically at the onset position of beats) with a very sharp increase and comparatively slow decrease. When people hear these rhythmic patterns, the magnitude of the oscillations in brain waves changes for frequencies which are related to the metrical structure of the rhythm [1].This provides an evidence that we can extract some information from the music we are listening to using EEG waves.

II. Method

There are two methods for tempo extraction in music signals - 1) Energy Method 2) Spectral Method
out of which the latter is more refined and better as compared to the former. Hence we will use the Spectral Method for our project which is described below. The Computation of Tempo Information involves first transforming the signal(either music audio or EEG signal) into a tempogram[3] which is a plot of time-tempo representation of a signal. Using 64 EEG channels placed on the scalp of user, one signal will be aggregated using Channel Aggregation Filter which is weighted sum of the channels followed by a tanh function to keep the output in the range [-1,1]. The Channel Aggregation filter weights are in turn learned using a Convolutional Neural Network(CNN) trained on the EEG dataset provided such that the resulting aggregated EEG signal captures the important characteristics of the music or signal. From the aggregated EEG time curve obtained, we need to find the novelty curve. For that, first we need to plot the spectrogram(frequency vs time plot) of the signal obtained and then apply logarithmic compression $Y = log(1 + |c|X)$ followed by differentiation to get the onset positions in the signal. The time interval between successive onset positions gives the local beat period thus computing the tempo value. But assuming the beat periodicities which we want to measure are already present in the time-domain EEG signal, we will consider EEG signal as the novelty curve. For pre-processing we will normalize the EEG signal by subtracting a local average curve computed using a time window which will make sure that the EEG signal is centered around zero and less frequent components are attenuated. The tempogram is computed using Short-term Fourier Analysis(described below) of the novelty curve. Now after computing the tempogram of a given music or EEG signal, we can extract a single tempo value from the tempogram by computing a tempo histogram H(τ) which represents how much present a certain tempo τ is within the entire signal. The highest peak in the tempo histogram represents the tempo value which is most dominant. But for EEG tempograms H^{EEG} is much noisier as compared to music histogram. Hence we will take first highest peak, make the histogram zero within $\pm$10 BPM of that peak and then do this for (n-1) subsequent peaks. Here n depends on the noise in EEG histogram as well as how much accurate the tempo value(w.r.t music tempo) we want. Suppose B1 = $\{b_1\}$, B2 = $\{b_1,b_2\}$... Bn = $\{b_1,b_2....b_n\}$ where bi = top i^{th} peak after doing the above process. Then the Minimum absolute BPM deviation(error) compared to audio tempo E(Bn, p) = $\min_{b \in Bn}$ $|b - p|^2$. We will try to minimize this error on the dataset provided by fine-tuning the CNN hyper-parameters.

A. *Short-term Fourier Transform:*

It is time dependent fourier transform(TDFT) of signals that changes periodically as the signal properties changes over time.

$$X_n(\omega) = \sum_{m=-\infty}^{\infty} x(m)w(n-m)exp(-j\omega m)$$

where w(n-m) is a window which determines the portion of x(n) used in the computation of X(ω).

1. tempo is speed of beats in music signals. tempo = 60/(period of beats) measured in beats per minute

2. Electroencephalography (EEG) is a non-invasive brain imaging technique that relies on electrodes placed on the scalp to measure the electrical activity of the brain

3. The tempogram of a signal is its time-tempo representation which reveals the periodicities in a given signal, similar to a spectrogram with tempo(beats per minute) on y-axis and time on x-axis with intensity representing the magnitude of that tempo value at any instant

References

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