Tempo Estimation from EEG Signals

EE325 project

Motivation

- ★ How does our brain analyse the music we hear?
- ★ Does the analysis of basic components like pitch and loudness depend on listener's level of attention and proficiency?

Why do we want to know these things?

We can use this information to design a Brain Computer Interface which interprets the music we imagine and retrieves it!

Introduction

What is Electroencephalography ?

It is a non-invasive(not involving the introduction of instruments into the body) brain imaging technique that relies on electrodes placed on the scalp to measure the electrical activity of the brain ERP(Event Related Potential)

- Music that we hear has beats which may be changing throughout the music.
- Fast music have very high speed of beats and hence high tempo while slow music have slow tempo.
- It is possible to use Music Information Technique(MIR) used for audio tempo extraction to extract tempo information from the EEG waves as well

How music information is reflected in brain waves ?

- Neural Oscillations happening in the brain are responsible for EEG waves
- These oscillations synchronize to rhythmic sequences and increase at the onset positions of the beats
- Therefore the positions of maxima correspond to note onset cues and indicate tempo information
- Hence we can regard the EEG signal as a mid level representation of the original audio signal which has undergone transformation in brain and EEG equipment

DataSet Formation

- DataSet used: OpenMIIR, which is a public dataset of EEG recordings:

i. Of 5 Participants(P)

ii. Listening to 12 music excerpts(M)

iii. Containing 5 trials per participant(T)

Therefore Total Number of Trials = |P|*|M|*|T| = 300

The data was recorded using a Bio-Semi Active –Two System EEG device which has 64 electrodes for EEG signals and 4 electrode for EOG(Electrooculography) data which records the eye movements.

The 12 Music Stimuli

ID	Name	Tempo	Length(s)
1.	Chim Chim Cheree(lyrics)	213	14.9
2.	Take me out to the Ballgame(lyrics)	188	9.5
3.	Jingle Bells(lyrics)	199	12.0
4.	Mary had a Little Lamb(lyrics)	159	14.6
11.	Chim Chim Cheree	213	15.1
12.	Take me out to the Ballgame	188	9.6
13.	Jingle Bells	199	11.3
14.	Mary had a Little Lamb	159	15.2
21.	Emperor Waltz	174	10.3
22.	Harry Potter Theme	165	18.2
23.	Star Wars Theme	104	11.5
24.	Eine Kleine Nachtmusik	140	10.2

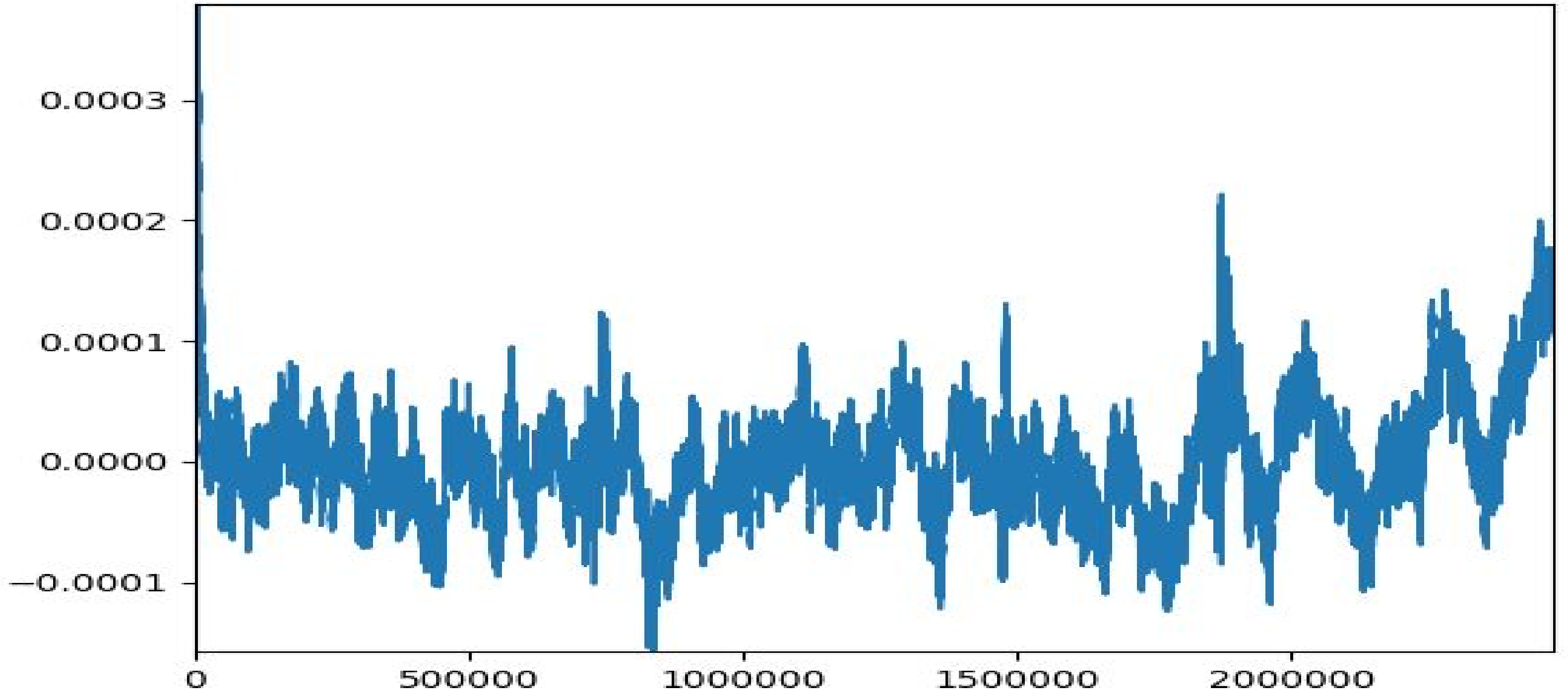
Aggregating the Channels and ICA

- We aggregate the 64 EEG channels into one signal.
- There is a lot of redundancy in these channels which we can exploit to improve signal to noise ratio.
- We use a pre-trained convolutional network based filter which is based on the technique known as similarity constraint encoding
- We use ICA to remove external artifacts in the EEG signal.
- ICA :- Cocktail Party Problem

Abstracting Novelty Curve from EEG Signal

- ➢After removing noise from the EEG signals using ICA, we extracted the Novelty Curve for the EEG data
- ➢For this, we aggregated the signals from the 64 electrode channels into a single EEG signal according to the impact of each electrode signal
- ➢This is done by using the weight matrix obtained by a Convolutional Neural Network (CNN) technique called Similarity Constraint Encoding(SCE) resulting in the aggregated EEG signal
- ➢Although the aggregated EEG signal can be interpreted as a kind of Novelty curve, we had to normalize the signal using a time moving average to ensure that the Novelty curve is centered around zero and resembles audio Novelty curve

Novelty Curve for EEG signals



Novelty Curve

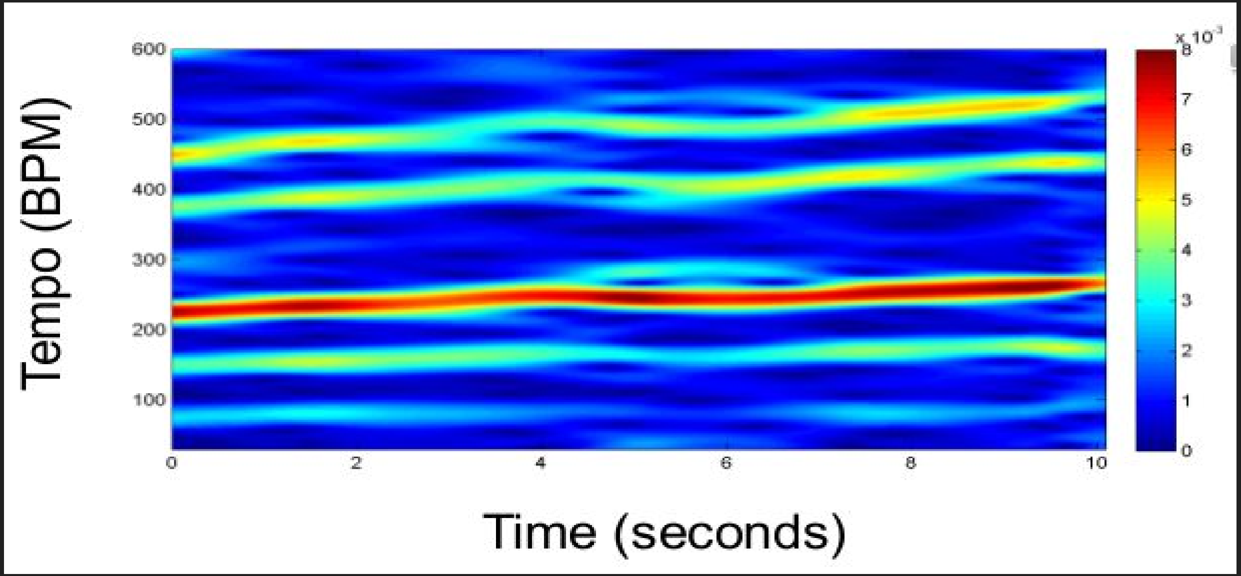
- A Novelty curve is a time varying curve, whose peaks denote the note onset positions
- For the audio signal, these peaks are placed similarly as the cue clicks
- Therefore, the time interval between the peaks indicates the local beat period

Tempo value = 60/beat_period

- However the Novelty curve obtained from EEG signals is much noisier
- This means that there is more noise in EEG tempogram compared to audio tempogram and so it is harder to locate a global tempo

Tempogram

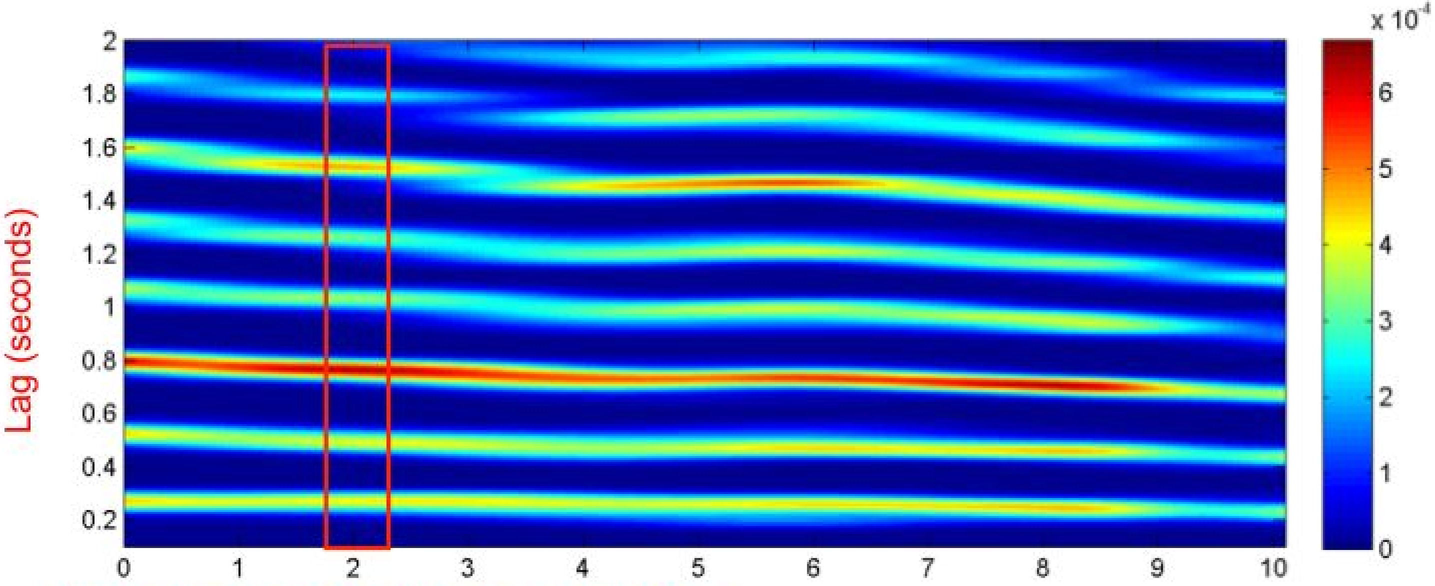
- A tempogram is a time-tempo representation that encodes the local tempo of a music signal over time.



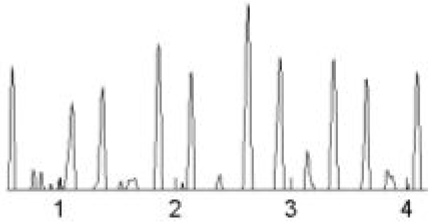
Tempogram...

- It reveals how dominant different tempi are at a given point of time
- The tempogram can be obtained from the Novelty curve by several methods:
    1) Short Term Fourier Transform(STFT) based method
    2) Autocorrelation based method
- We employed the Autocorrelation method in order to get the tempogram because in this method, novelty curve is compared with time-lagged local (windowed) sections of itself and hence it reveals novelty self-similarities

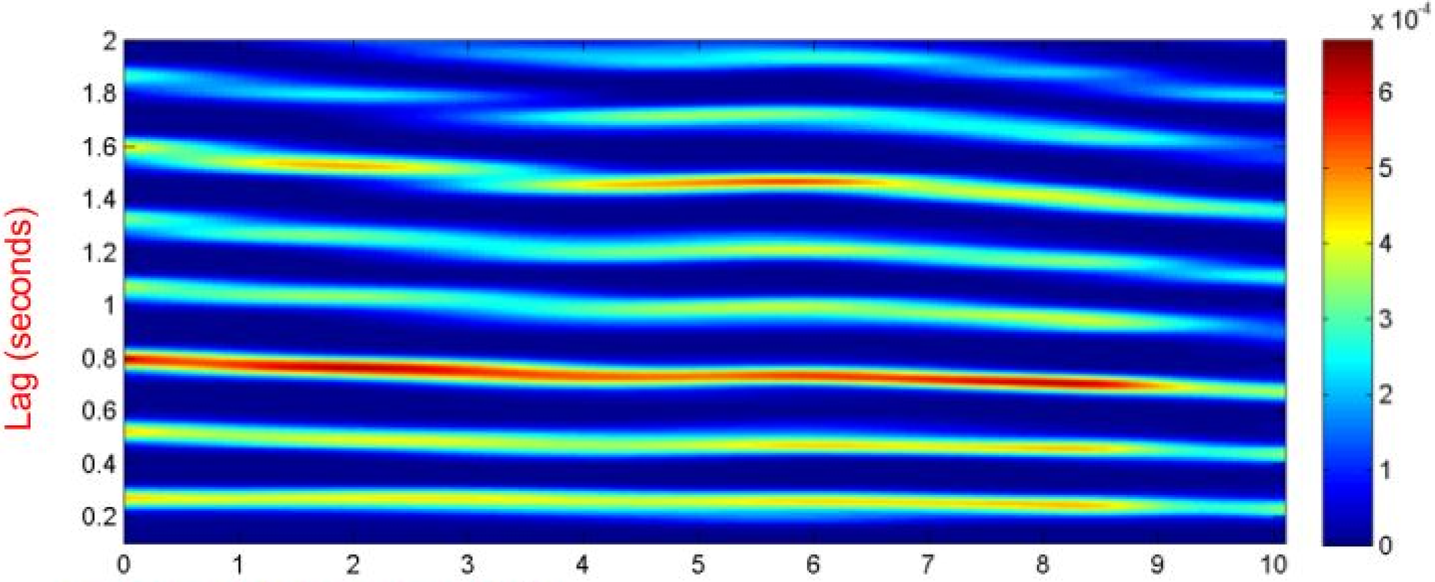
Tempogram (Autocorrelation)



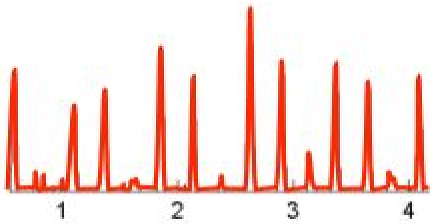
Windowed autocorrelation



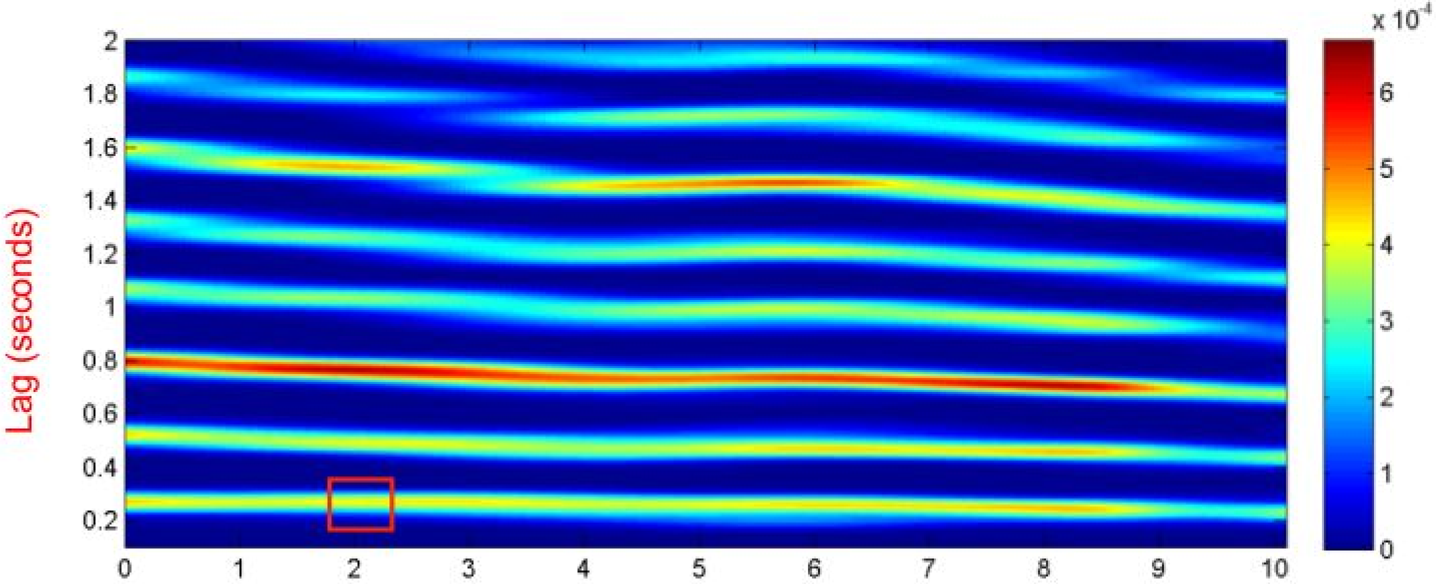
Tempogram (Autocorrelation)



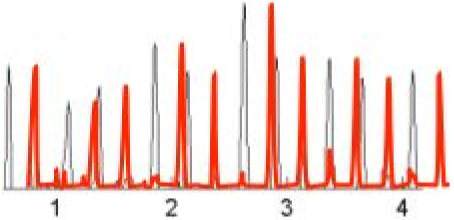
Lag = 0 (seconds)



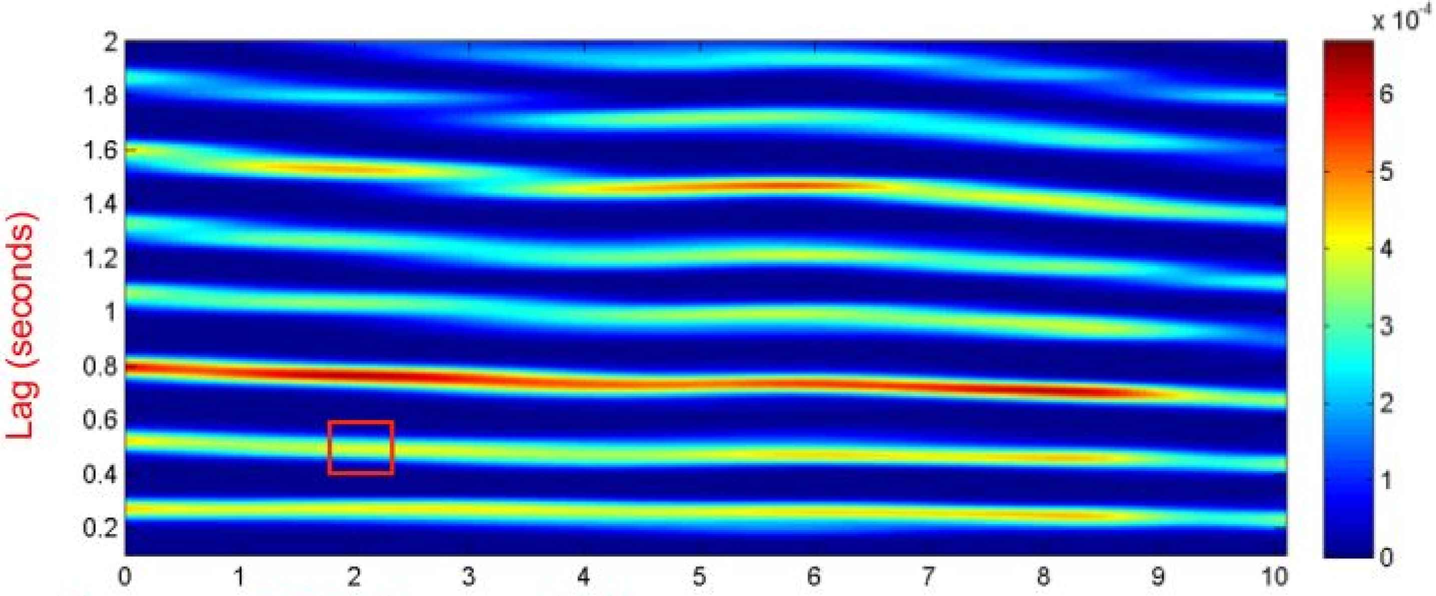
Tempogram (Autocorrelation)



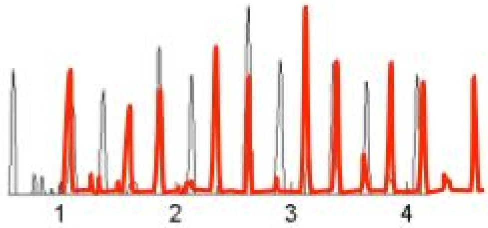
Lag = 0.26 (seconds)



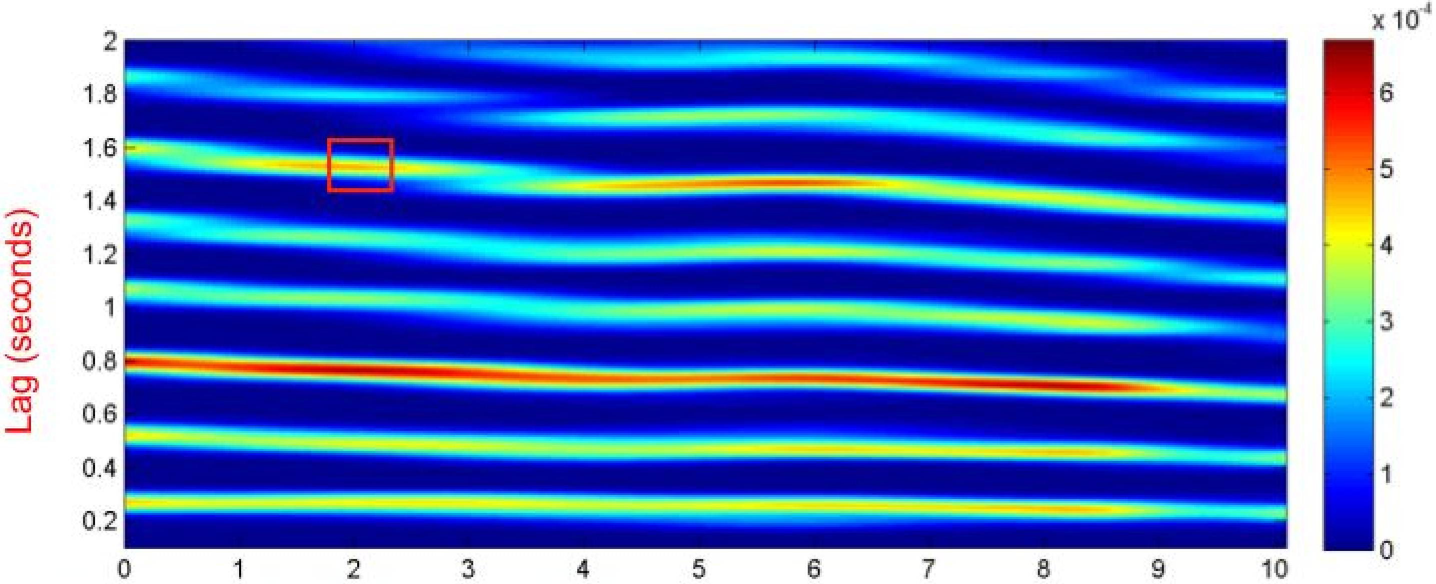
Tempogram (Autocorrelation)



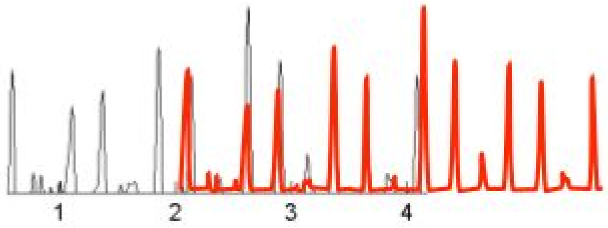
Lag = 0.52 (seconds)



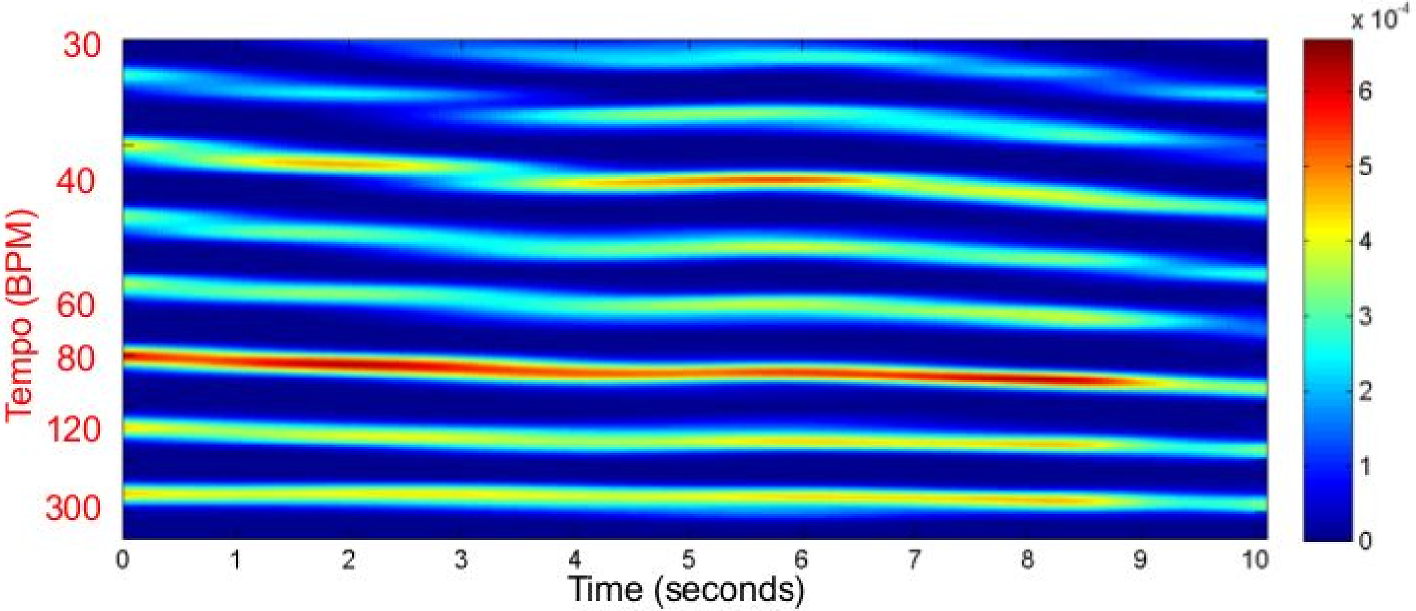
Tempogram (Autocorrelation)

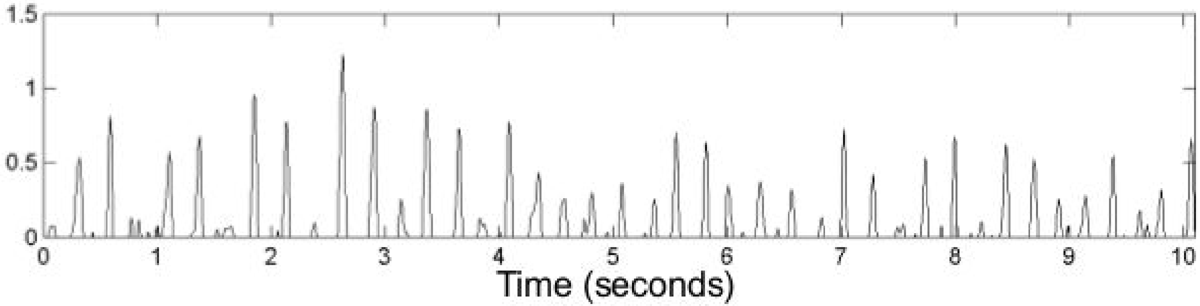


Lag = 1.56 (seconds)

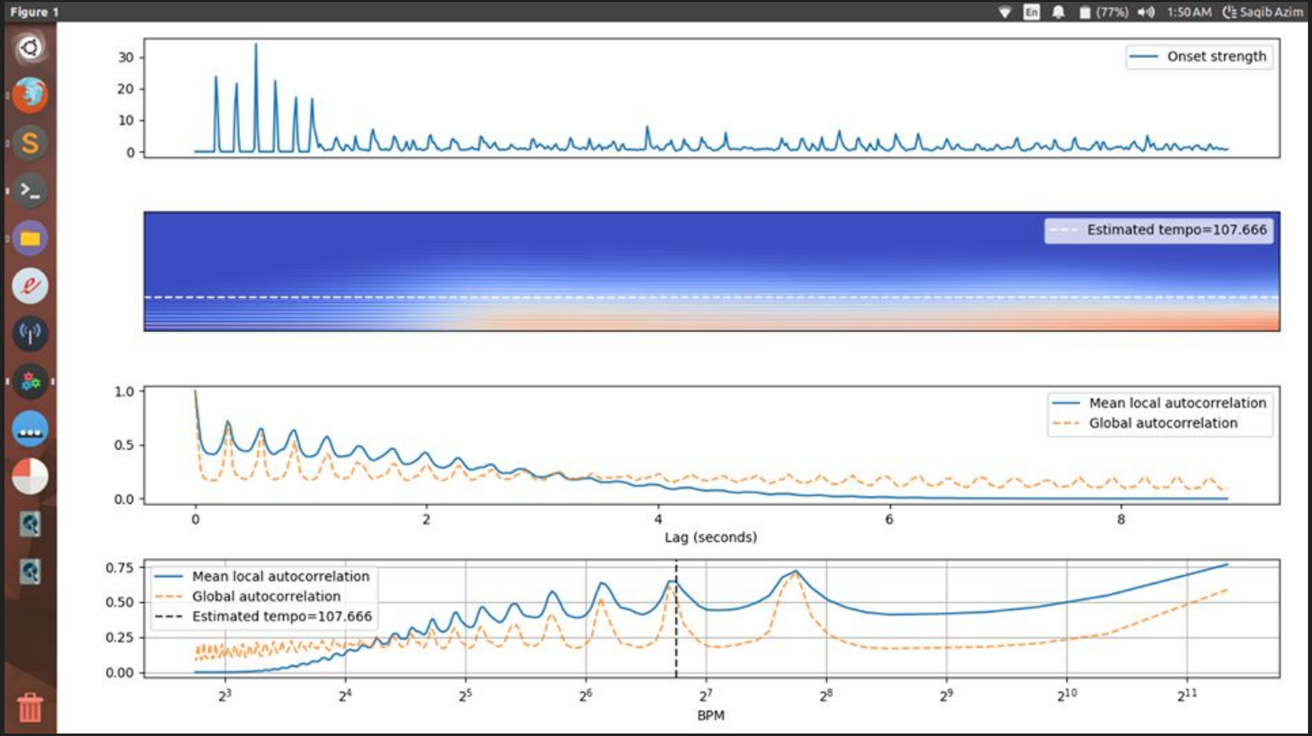


Tempogram (Autocorrelation)



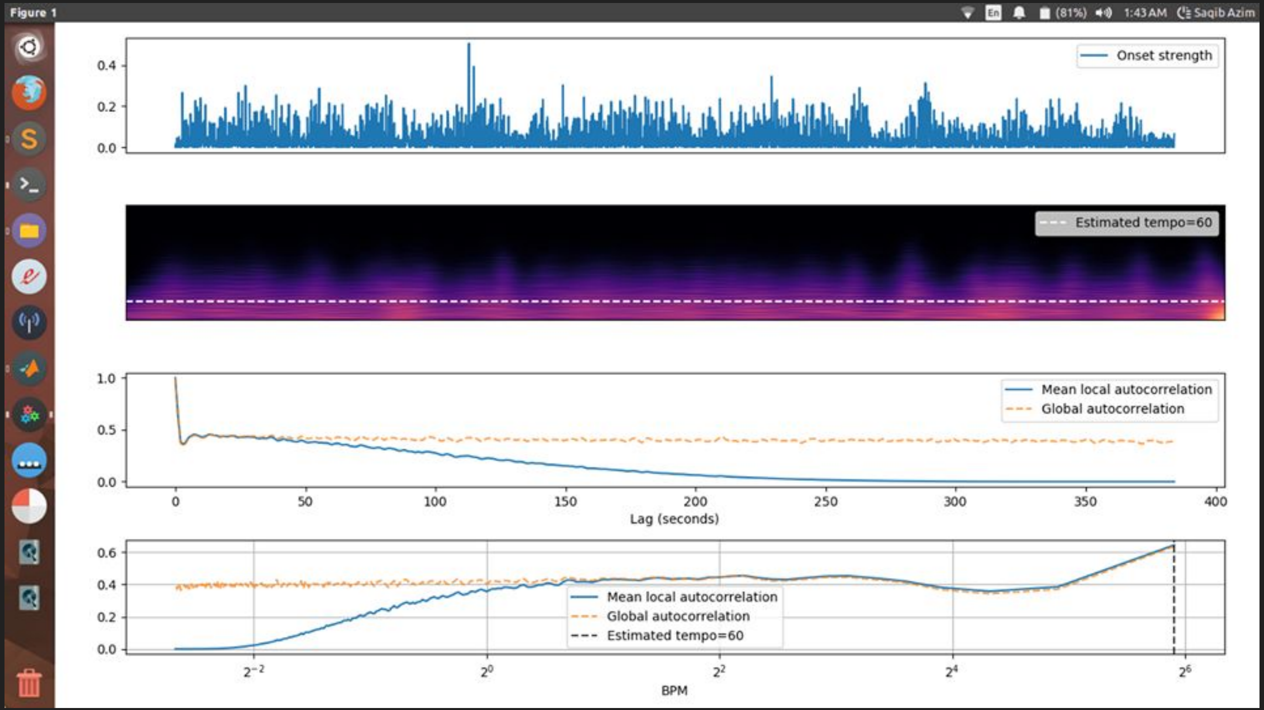


Comparison between tempograms from Music and EEG



Tempogram and Autocorrelation for music signal

Comparison between tempograms from Music and EEG



Tempogram and Autocorrelation for EEG signal

Observations

- EEG signals tempogram came out to be much noisier as compared to music signal tempogram
- Hence we use a tempo histogram which is essentially a time aggregated tempogram
- A value on the histogram represents how recent a tempo is within the signal
- The peak of the histogram thereby obtained corresponds to the main tempo of audio signal
- In the case of simple music, the EEG tempogram has only a few bright spots but as the complexity increased the number of peaks in the HIstogram also increased

Conclusion

- Tempo estimation from the EEG signals is possible using techniques similar to those employed for audio music
- However the estimated tempo is not always accurate and depends on the complexity of the music stimulus used
- We also found that the tempo retrieved from the EEG signals is independent of the proficiency of the listener
- Deviation between estimated and actual tempo can be minimized by using different fusion techniques which average the tempo histograms over trials and participants for a given music stimulus

THANK YOU

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