General research overview,
Topic: bpm music analysis
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I have generally been diving into the techniques that are useful when doing BPM analysis using FFT and or filters.

The goal with a beat tracking algorithm would best be phrased as the following:
To make computer analyses a piece of music and determines the periodic sequence of the beat.

In trying to do this there are a lot of challenging problems to run into.
For example:
-Not being able to detect a clear pulse, because of on unclear audio signal.
-Sudden tempo chances in the music, live music without a steady pulse.

The topics I will look at in short are:
Onset detection: detect on onset in the musical data

Beat tracking: find a pattern in the extracted onset data

Tempo estimation: based on the extracted beat pattern estimate the BPM

Energy based onset detection: (in short)

1. Take the audio waveform
2. Filter out the audio noise you don't need
3. Square it (so you only look at the positive values)
4. Look only at energy chances in the music (ex. Spectral flux)
5. Detect peeks above certain interval

Useful techniques term to know:

Short term Fourier Transform:
This is basically an FFT but combined with a windowing function that breaks the FFT up into smaller "short term" data to analyze.
The Short term Fourier Transform or "SFFT" in short in used a lot in beat tracking algorithms

Direct wavelet transform:
Also used a lot in beat tracking because unlike the FFT the DWT (Direct wavelet transform) also captures time based information unlike the FFT which only captures frequency and phase information.

Detection analysis techniques:

Energy flux:
This is calculated by taking the short term Fourier transform of an audio signal
And the magnitude differences of the RMS signal are detected,
This technique works well on percussive note onset detection

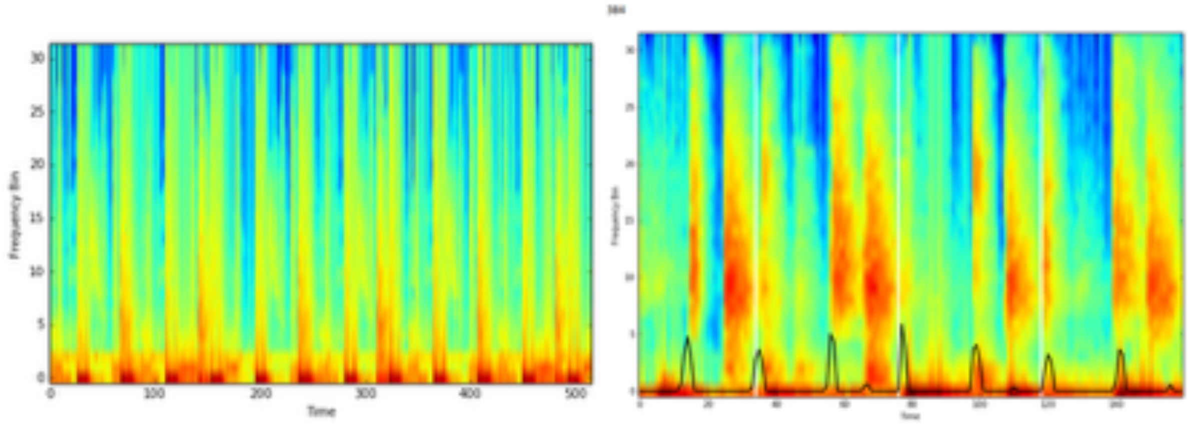
Spectral flux:
This technique looks at the current and previous FFT signal and compares the two.
This makes it possible to detect the big energy chances in the audio data.

Complex spectral difference:
Detects if there is a big chance in the magnitude of the audio signal just like the spectral flux, but this equation also detects phase differences.
The amplitude and phase data of the current frame, are based on the previous two data points of the FFT. (this system assumes its working with constant amplitude and phase chances)

Tempo estimation:
In short the tempo of your BPM is calculated easily by the following formula:
BMP= 60/interval between two onsets

Comb filter bank:
You can use an comb filter on an audio signal.
Basically you have to measure every resonating. The amount a certain band is resonating can periodically predict a rhythmic hierarchy in an audio signal.

Interval histogram:
As shown in the two pictures below. The gathered data of an audio histogram can be used to extract the BPM of a piece of music.
This could even be used in machine learning be giving the system the audio histograms of a lot of different styles of music and their BPM ratio. To let the neural network compute what the BPM is of a peace of music based on a spectrogram.



picture 1&2

Tempo estimation function:
In short compare the onset interval data, but use an error margin for ex. 4% of the original signal. This is done to make the algorithm more capable of detection the BPM of a musical piece when the timing is not spot on al the time (Ex. in a live performance).

Useful audio analysis terms in short:

-Spectral flatness:
Detects noisiness of a signal.
-Spectral percentile:
Looks at how big the percentage is between the lowest frequently and the highest cutoff band

-spectral flux:
compares current FFT signal with the previous one to measure the amount of energy fluctuation in the FFT.

-MFCC:
this is the mescale and the FFT combined. (kind of)
it uses the FFT of the FFT which can provide information about the frequently spectrum kind of like data viewed on an equalizer.

This image shows the average BPM tracking technique pretty good:

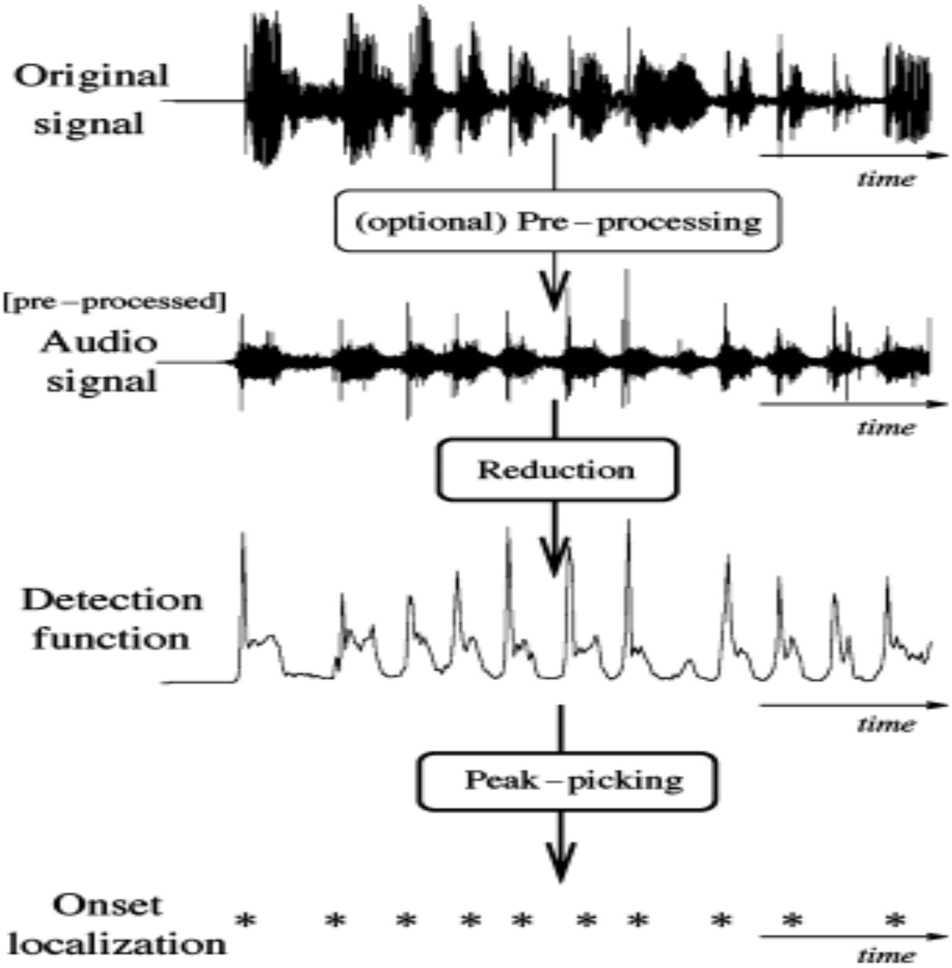


Fig. 2. Flowchart of a standard onset detection algorithm.

picture 3

Sources:

Form the internet:

1. http://soundlab.cs.princeton.edu/publications/2001_amta_aadwt.pdf
2. https://www.audiolabs-erlangen.de/resources/MIR/2017-GI-Tutorial-Musik/2017_MuellerWeissBalke_GI_BeatTracking.pdf
   (general info)
3. https://nlml.github.io/neural-networks/detecting-bpm-neural-networks/
   (machine learing bpm detection)
4. http://mziccard.me/2015/05/28/beats-detection-algorithms-1/
   (general info)
5. http://www.ismir.net/resources.php
   (general info)

books:
(and a few more which I unfortunately cant remember the names of, but their contribution was not that big☺)
book mostly used for general info.
-music data analysis, foundations and applications
-the computer music tutorial – Curtis Roads
-audio content analysis - Alexander Lerch

pictures:
picture 1 &2: https://nlml.github.io/neural-networks/detecting-bpm-neural-networks/
picture 3: https://www.badlogicgames.com/wordpress/?p=161