



Introduction to **Audio Content Analysis**

module 9.4: beat histogram

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introduction

overview

corresponding textbook section

section 9.4

■ lecture content

- introduction of the beat histogram
- low level features used to describe rhythmic properties

■ learning objectives

- explain the terms beat histogram and beat spectrum and how they related to each other
- describe two low level features derived from the beat spectrum and discuss their musical meaning and limits



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beat histogram

problem statement

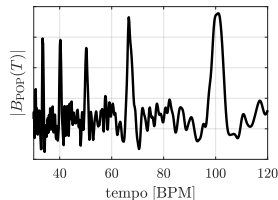
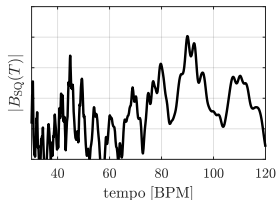
- previously introduced low-level features not suitable for temporal or rhythm description
 - onset, beat, and downbeat detection either error prone or complicated
- ⇒ “robust” low level representation focused on tempo and rhythm:
- beat histogram/spectrum**

beat histogram

introduction

beat spectrum or beat histogram:

- x-axis (BPM or inter-onset-time)
- y-axis ('strength' of periodicity or number of occurrences)
- compact representation of periodicities



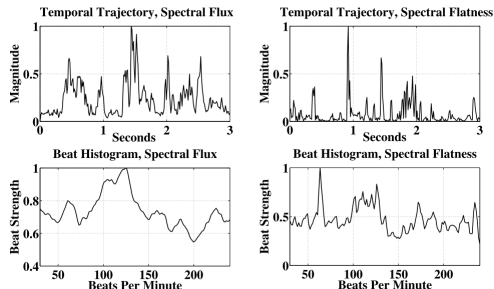
beat histogram

input

1 option 1: novelty function

- time domain features: envelope, rms
- spectral differences: flux, ...
- any other feature meaningful for rhythm description

2 option 2: series of onset times



graph from¹

¹A. Lykartsis and A. Lerch, "Rhythm Features for Musical Genre Classification Using Multiple Novelty Functions," in *Proceedings of the International Conference on Digital Audio Effects (DAFX)*, Trondheim, Norway, 2015.

beat histogram

transform

- 1** option 1: frequency transform
 - magnitude spectrum
 - filterbank
- 2** option 2: ACF
 - ACF maxima indicate periodicity periods
- 3** option 3: histogram
 - measure Inter-Onset-Intervals (IOIs)
 - sort them into bins and plot number of occurrences

beat histogram

feature examples

■ statistical features

- mean, centroid, standard deviation, kurtosis, ...

■ peak features

- value and position of absolute max
- ratio (value and position) of strongest and 2nd strongest peaks

■ other features

- flatness, crest, high frequency content, MFCCs (??), ...
- features from ACF of beat histogram

beat histogram

feature examples

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beat histogram

feature examples

■ statistical features

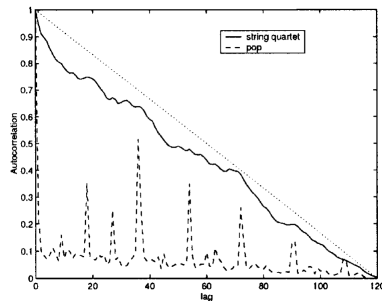
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plot from²

² J. J. Burred and A. Lerch, "Hierarchical Automatic Audio Signal Classification," *Journal of the Audio Engineering Society (JAES)*, vol. 52,

rhythm description

open questions

- what are the salient perceptual properties of rhythm?
- what rhythms are perceptually similar?
- should a rhythm description be tempo dependent or not?
- what role does micro-timing play?
- should rhythm descriptors be normalized to bar length?

summary

lecture content

■ beat histogram or spectrum

- some frequency domain representation of novelty/ onsets
- usually characterizing the periodicities

■ beat histogram features

- low level features characterizing the beat spectrum
- often statistical descriptors
- easy to extract but limited meaning

■ usefulness of the beat histogram

- relatively compact representation of periodicity
- lacks phase → not a good rhythm description

