Introduction to **Audio Content Analysis**

module 9.4: beat histogram

alexander lerch

introduction
overview

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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

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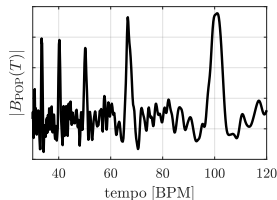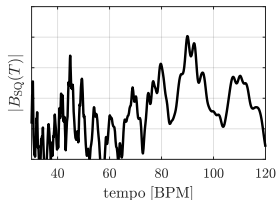Tech | Technology
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- previously introduced low-level features not suitable for temporal or rhythm description
- onset, beat, and downbeat detection either error prone or complicated

$\Rightarrow$ "robust" low level representation focused on tempo and rhythm:
   beat histogram/spectrum

beat histogram
introduction

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beat spectrum or **beat histogram**:

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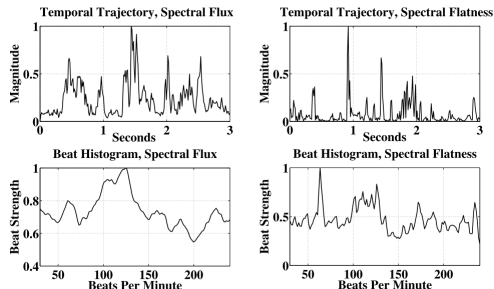
- compact representation of periodicities

matlab source: plotBeatHistogram.m

beat histogram
input

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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 from[1]

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[1] A. 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

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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

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- **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

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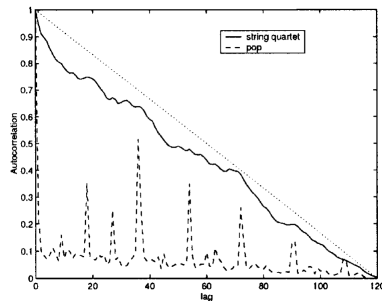College of Design

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plot from[2]

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[2] J. J. Burred and A. Lerch, "Hierarchical Automatic Audio Signal Classification," *Journal of the Audio Engineering Society (JAES)*, vol. 52, no. 7/8, pp. 724–739, 2004.

rhythm description
open questions

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- 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

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- **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 $\rightarrow$ not a good rhythm description