



# Introduction to **Audio Content Analysis**

Module 9.4: Beat Histogram

alexander lerch

# 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



# 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



# beat histogram

## problem statement

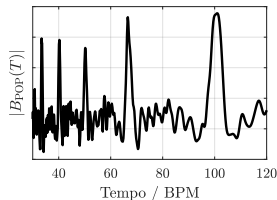
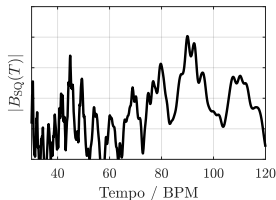
- previously introduced low-level features not suitable for temporal or rhythm description
  - onset, beat, and downbeat detection either error prone or complicated
- ⇒ “robust” low level representation focused on tempo and rhythm:
- beat histogram/spectrum**

# 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



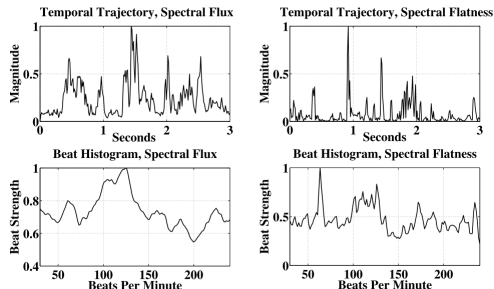
# beat histogram

## 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 from<sup>1</sup>

<sup>1</sup>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

- 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

### ■ 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

### ■ statistical features

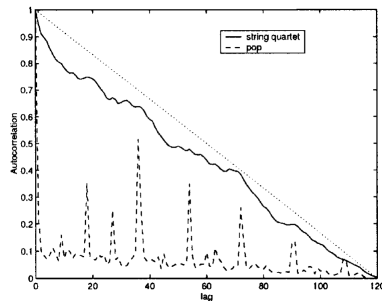
- mean, centroid, standard deviation, kurtosis, ...

### ■ 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



plot from<sup>2</sup>

<sup>2</sup> 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

