

## Tempo and beat analysis of acoustic musical signals

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ISE575: Feb 3, 2005

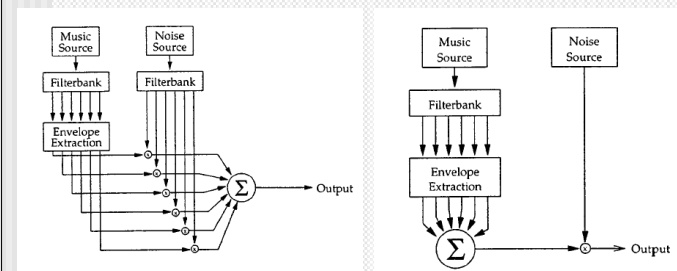
## Introduction

- Goal: automatic extraction of rhythmic pulse (beat-tracking)
  - Like people do when they foot tapping with music
- Beat: “the sense of equally spaced temporal units”
  - Defining tempo
- Grouping, Strong/Weak relationship is not considered.

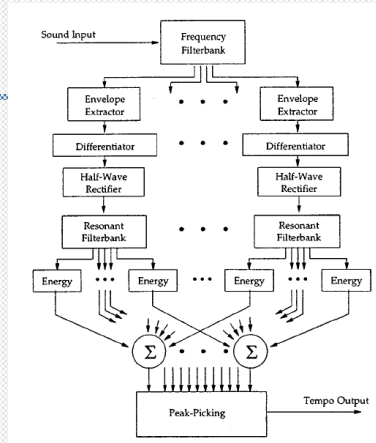
## Previous work

- Previous work focus on symbolic data, or try to extract high-level information before tracking beat.
- This research try to avoid the “transcriptive” analysis.

## Psychoacoustic demonstration



## Algorithm



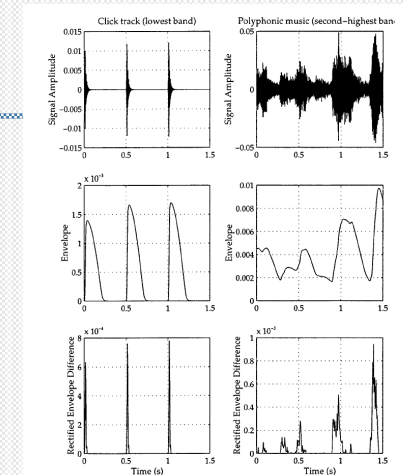
## Frequency Filterbank

- 6 filter divide signal to 6 subband:
  - ~200, 200~400, 400~800, 800~1600, 1600~3200, 3200~
- Sixth-order elliptic filter:
  - Sharp cutoff
  - 3dB ripple in passband
  - 40dB of rejection in stopband

## Envelope Extracting, Differentiator, Rectifier

- Rectified-and-smooth:
  - Smooth by a 200-ms half-Hanning window.
- Decimation:
  - Downsample to 200Hz sampling rate.
- Differentiated
- Half-wave rectified

## Examples

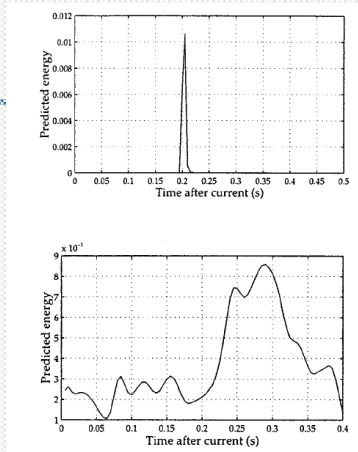


## Resonators Filterbank

- Each comb filter has the form:
  - $y(t) = \epsilon y(t-T) + (1-\epsilon)X(t)$
  - Giving larger output while the input is of period T (or multiple, factor of T).
- Output value from different subband filter with the same T are added to determine the tempo

## Beat Phase

- The time when the next beat will arrive can be predicted:
  - The value in the delay lattices can be viewed as “predicted output”, in the case of zero input.
  - Performed every 25ms.



## Comparison with the autocorrelation methods

- Advantage:
  - Gives phase information, predict next impulse.
- Disadvantage:
  - Less efficient in memory usage.

## Parameters to tune

- Frequency filterbank
- Envelop sampling rate
  - Oversampling is required
- Number of resonators
- Analysis frame rate

## Validation

Genre	No. of cases	Correct	Partial	Wrong
Rock	17	13	3	1
Country	3	3	0	0
Urban	9	7	1	1
Latin	5	3	2	0
Classical	9	4	4	1
Jazz	8	3	1	4
Quiet	3	2	0	1
Reggae	2	2	0	0
Non-Western	4	4	0	0
Total	60	41	11	8

## Conclusion

- An algorithm for beat-tracking digital format music.
- Some problem unsolved:
  - Best number of bands used?
  - Errors:
    - Upbeat/downbeat, quarter-note/ eighth-note discriminating.
  - Other Structure: two-level?