

## Goals and Achievements

- Detect the chord sequence from arbitrarily instrumented music.
  - ✗ Achieved accuracy rate: 65%
- Integrate music theoretical knowledge to enhance recognition accuracy:
  - ✗ Use of beat tracking, key detection and chord sequence smoothing
- Support precise evaluation the same as immediate feedback:
  - ✗ Tools to compare hand-labelled and generated chord-files and compute chord confusion matrices
  - ✗ Synthesize the detected chord-sequence and mix it with the original signal

## How To Detect Chords - The Algorithm

### Key Detection + Reference Chord Filtering

The key of the song is detected and used as a filter for the reference chords. From 24 possible major and minor chords, 10 chords are thus preselected.

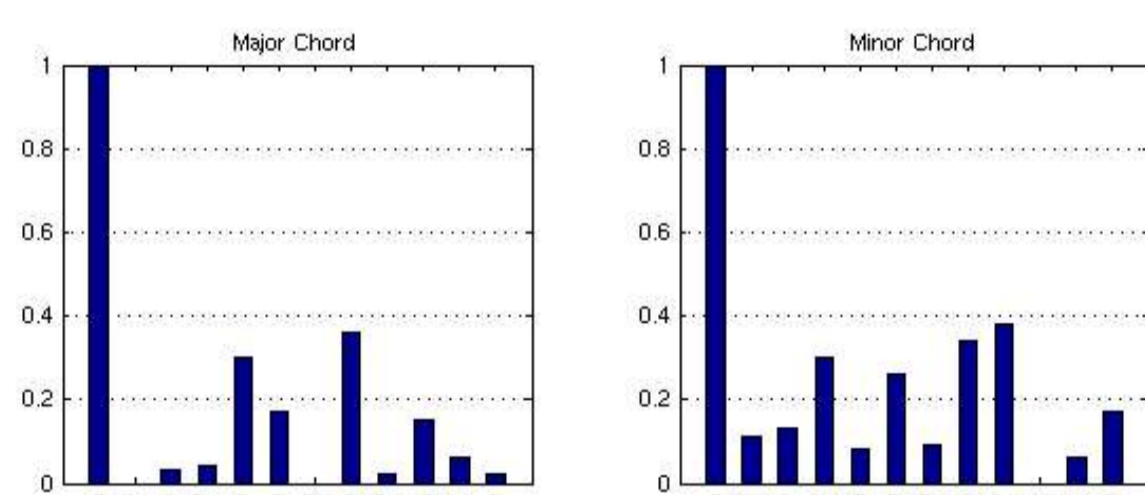
In our tests key detection and chord filtering increased the average accuracy rate by 13%.

| pitch(function)            | c(T) | d(Sp) | e(Dp) | f(S) | g(D) | a(Tp) | b      |
|----------------------------|------|-------|-------|------|------|-------|--------|
| chords proper to the scale | C    | d     | e     | F    | G    | a     | G7(b-) |
| Secondary dominants        | G    | A     | B     | C    | D    | E     |        |
| Secondary subdominants     | F    | G     | A     | Bb   | C    | D     |        |

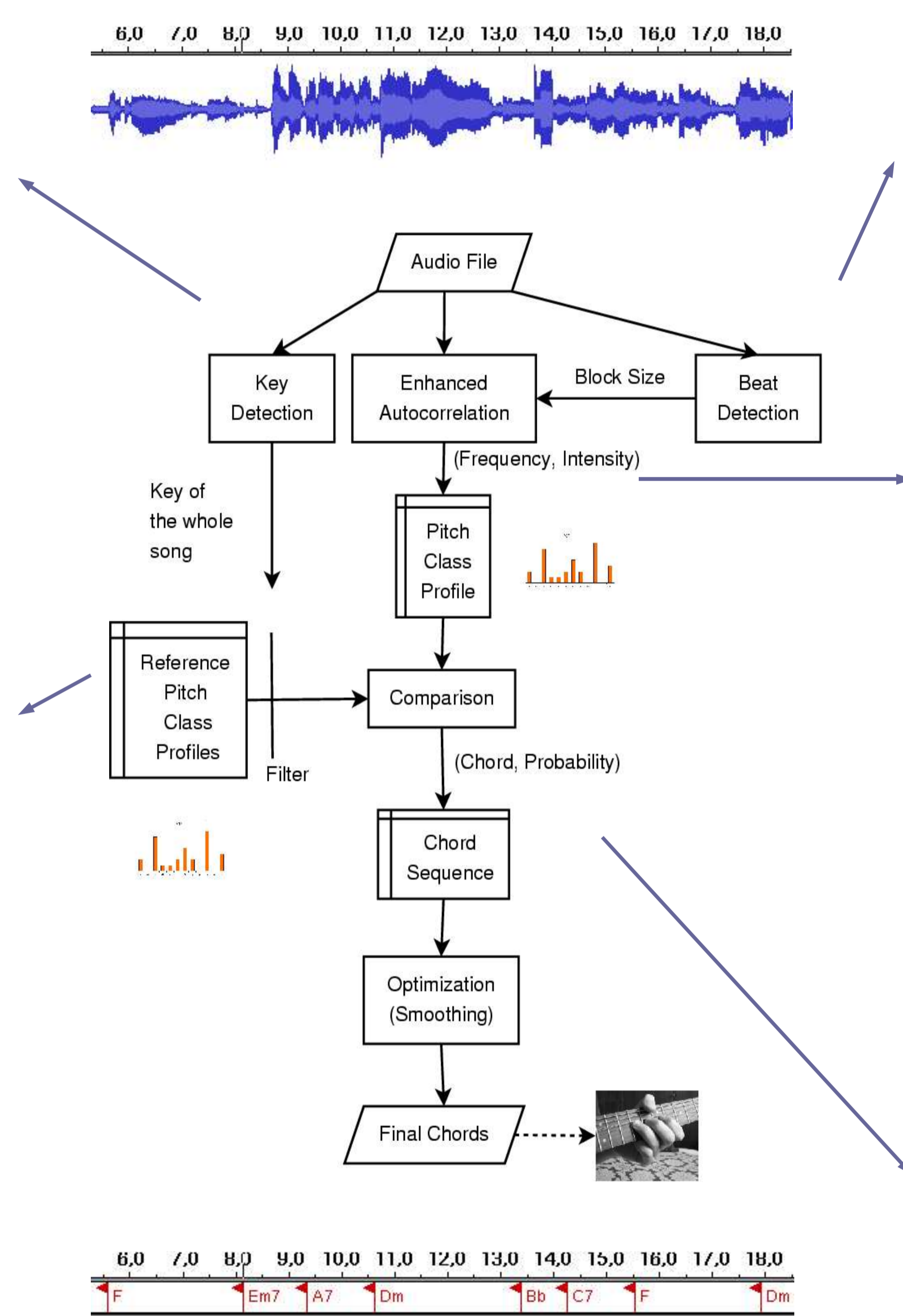
Chords listed according to their functions that pass the filter for key C-major

### Reference Pitch Class Profiles (PCPs)

A PCP is a vector of twelve elements, each representing the energy at one pitch class. For each chordtype that shall be detectable, one reference PCP is stored that represents the standard PCP of this chordtype. The reference PCPs of all chords of this chordtype (E.g. C-Major, D-Major, G-Major, ...) are obtained by shifting the PCP by the number of semitones between C and the relevant chord root.



Reference PCPs for major and minor chords obtained by training

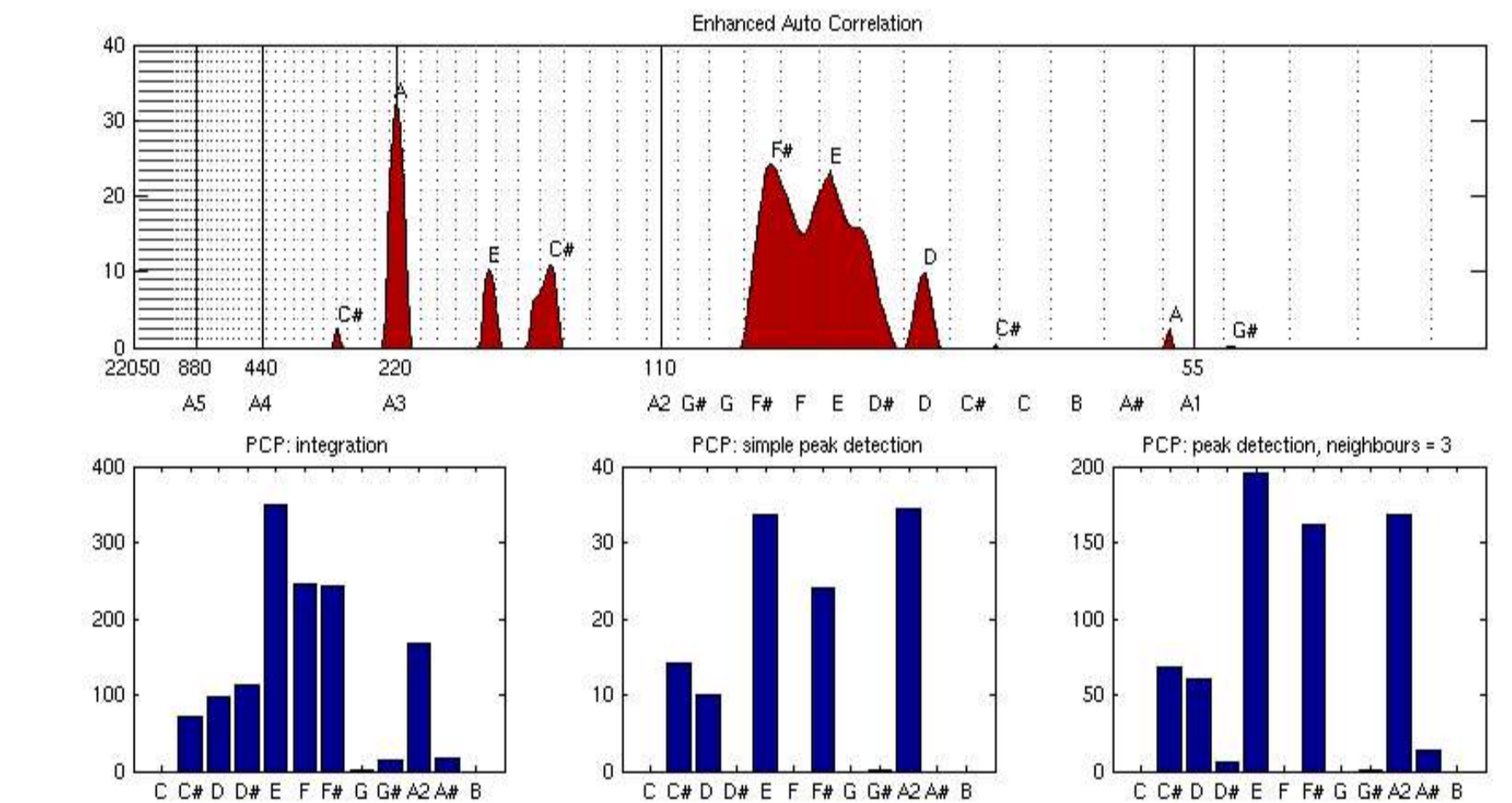


### Beat Tracking

The pulse of the song (the frequency at which you would clap your hands to the song) is calculated. The song is split into blocks that reach from one beat time to the next. In our tests beat tracking increased the average accuracy rate by 6%.

### Frequency Detection and PCP Generation

For each block the frequency spectrum is calculated using enhanced autocorrelation. Before analysing the frequency spectrum it is transformed into a smaller more compact representation, the Pitch Class Profile (PCP). This is a vector of twelve elements, each representing the energy of the signal at one pitch class.

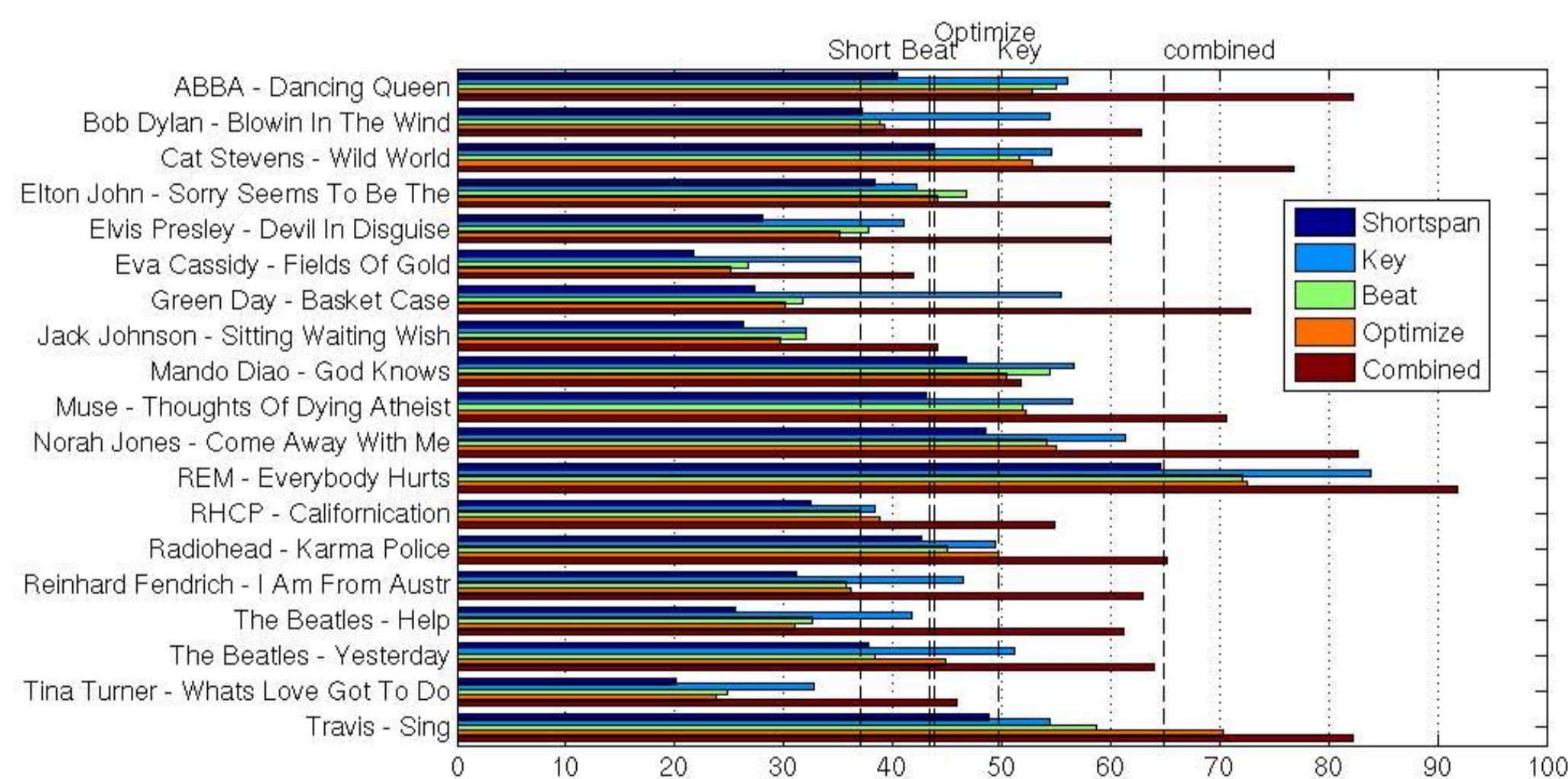


Spectrum and corresponding PCPs generated by 3 different algorithms

### Chord Identification and Optimization

The calculated PCP's are compared to the reference chordtype-PCP by calculating the linear distance of these vectors. Finally a smoothing algorithm rates each chord according to the number of chord changes around it. In our tests beat tracking increased the average accuracy rate by 7%.

## Evaluation Results



A testset of 19 songs has been handlabelled and evaluated. Our algorithm achieved an accuracy rate of 65%.

The developed chord detector has a modular design, where each module can be switched on and off independently. In order to prove the effectiveness of each module the tests have been performed separately for each module.

- Accuracy with all of the modules turned off: 37%
- Accuracy with only beat detection turned on: 43%
- Accuracy with only smoothing turned on: 44%
- Accuracy with only key detection turned on: 50%
- Accuracy with all modules turned on: 65%

## Additional Tools

### Acoustic chords validation

Genchords can mix the original song and the generated chords and can play them both in stereo mode. The musician validates the chords while listening.



### Exact evaluation using truth files

Hand labelled truth files can be compared to generated chord-sequences and absolute and relative times of corresponding chords are computed. In addition confusion matrices can be generated that allow for a better interpretation inaccuracies.

|         | Guessed |      |      |       |      |      |      |
|---------|---------|------|------|-------|------|------|------|
|         | Bbmaj   | Cmaj | Cmin | Ebmaj | Dmaj | Fmaj | Gmin |
| T Cmaj  | 3.6     | 0.0  |      |       |      |      | 0.1  |
| r Cmin  |         | 2.3  | 7.8  | 0.9   | 0.1  | 1.3  | 4.0  |
| u Ebmaj |         |      |      | 0.0   |      |      |      |
| t Dmaj  |         |      |      |       | 1.8  |      | 3.7  |
| h Fmaj  |         |      |      |       |      | 2.0  | 5.4  |
| Gmin    |         |      |      |       |      | 2.8  | 0.2  |
|         | 2.8     | 0.5  | 0.5  | 2.8   |      | 0.2  | 11.0 |

Confusion matrix showing confusion times in seconds  
Correct identifications are displayed in black (=diagonal values)  
Confusion times are displayed in red