“IS IT TRUE ?” AUDIO RECOGNITION AND TAMPERING DETECTION AS MEANS FOR AUTHENTICATING COMMUNICATIONS

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OVERVIEW

- Current challenges
  - Security
  - Authentication
- Technical means to proof tampering
  - Robust hashes (audio identification)
  - Recognize melodies
  - Identify editing of audio recordings
- Conclusions

BACKGROUND

- Digital audio everywhere
  - 20 million tracks of music
  - Every phone conversation
  - Billions of devices record / play back audio of all kinds

- But is it true ?
  - We all know that pictures can be modified
  - Audio has the same possibilities
    - Delete parts to change meaning
    - Re-use the artistic work of others

SOME SCENARIOS (SOME OF THEM HAVE PROBABLY NOT YET HAPPENED)

- Plagiarism:
  - A short piece of music is re-used as is
  - A melody is used in a different context
- Editing the original source
  - Some words are deleted from a sentence to change the meaning
  - An original source is used as a material to create a new sentence
- Resynthesizing speech:
  - Analysis of speech specifics, then synthesis with new meaning

SECURITY / AUTHENTICATION

- Use cryptography to secure the transmission
  - Not the topic of this talk
- Use hash functions or similar to authenticate the source of the transmission
  - Probably the only solution against the most advanced attacks
  - Again not the topic of this talk, but:
  - Can we produce robust hash functions for audio ?
    - Yes, see the next slides

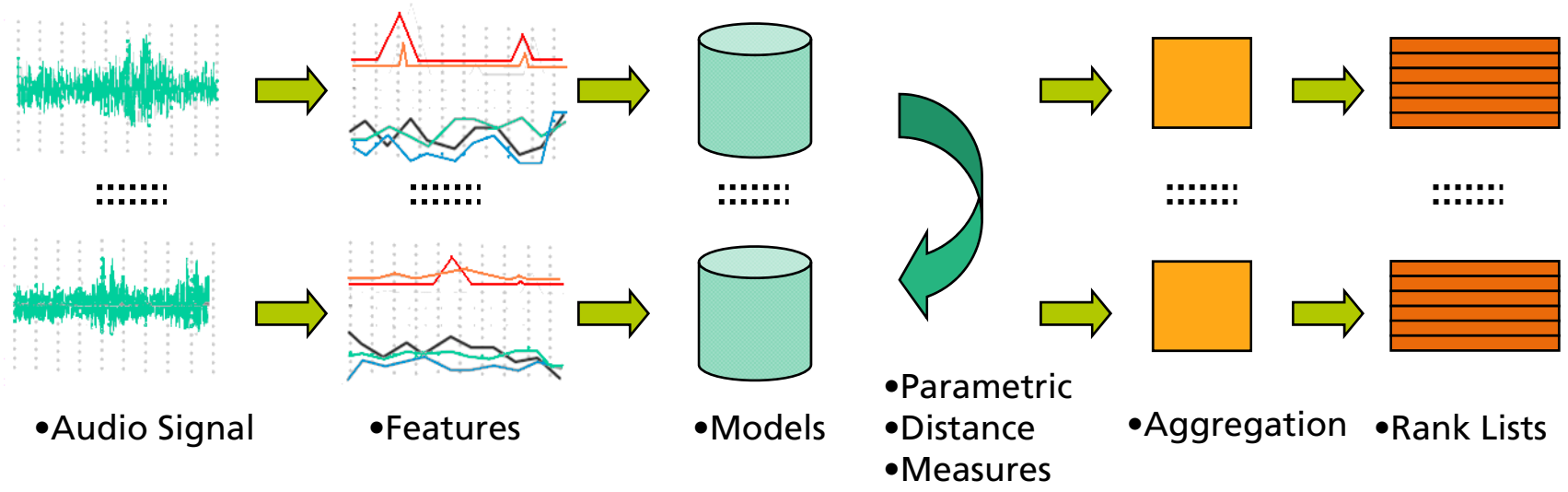
AUDIO IDENTIFICATION, AUDIO SIMILARITY: BASICS

- Audio identification is used in Apps like Shazam, SoundHound
  - Technically mature field
  - Use of machine learning
  - Accuracies approach 100 % even in difficult conditions

- Audio recognition
  - Much more difficult
  - We can recognize melodies etc.
  - Examples follow

AUDIO SIGNAL ANALYSIS: BASIC TASKS

- Audio Similarity Search: Query-by-Example → Common approach
  - Audio model given by distribution of low-level audio features
  - Distance between models → indicates similarity



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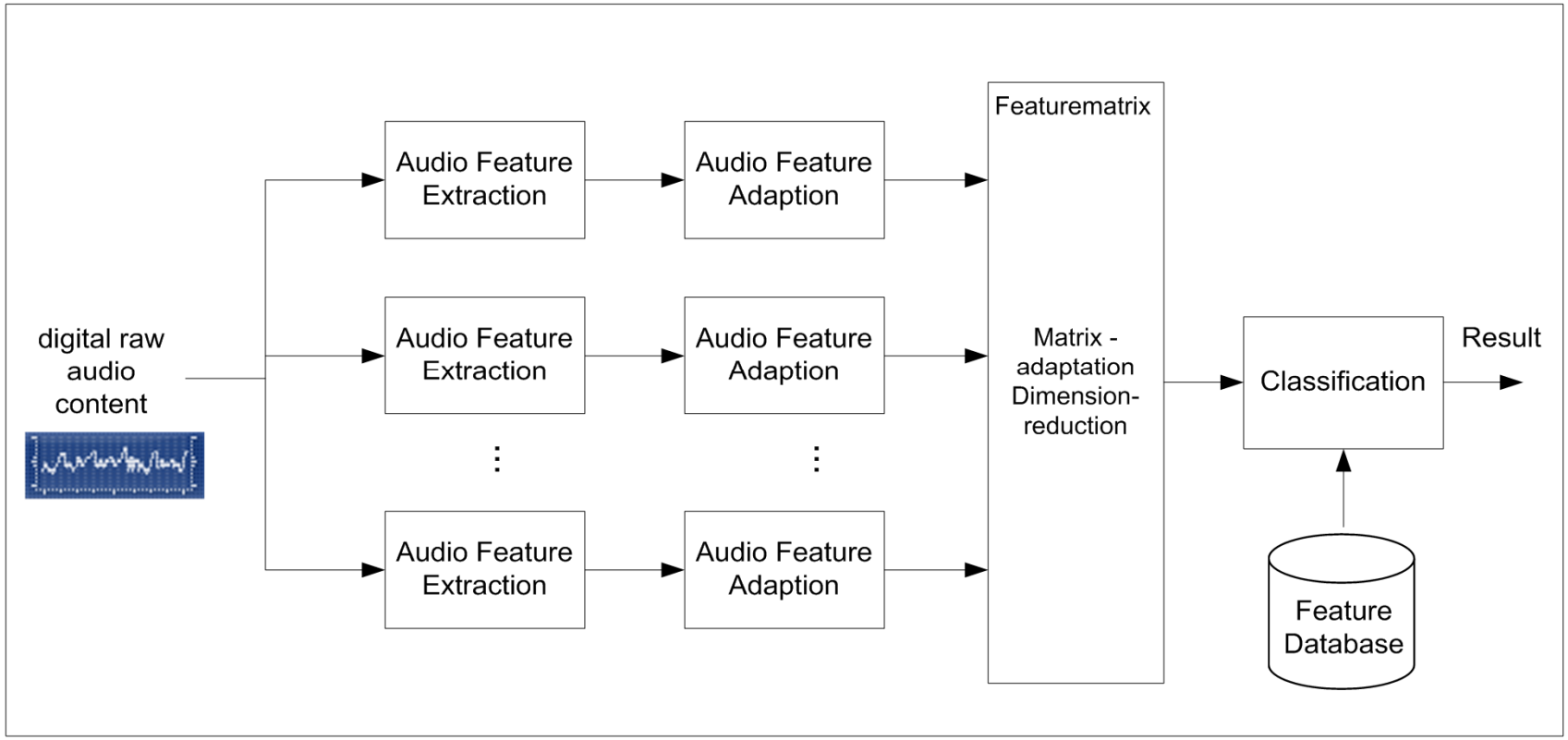
AUDIO SIGNAL ANALYSIS: BASIC TASKS

- Audio Pattern Recognition → Machine Learning



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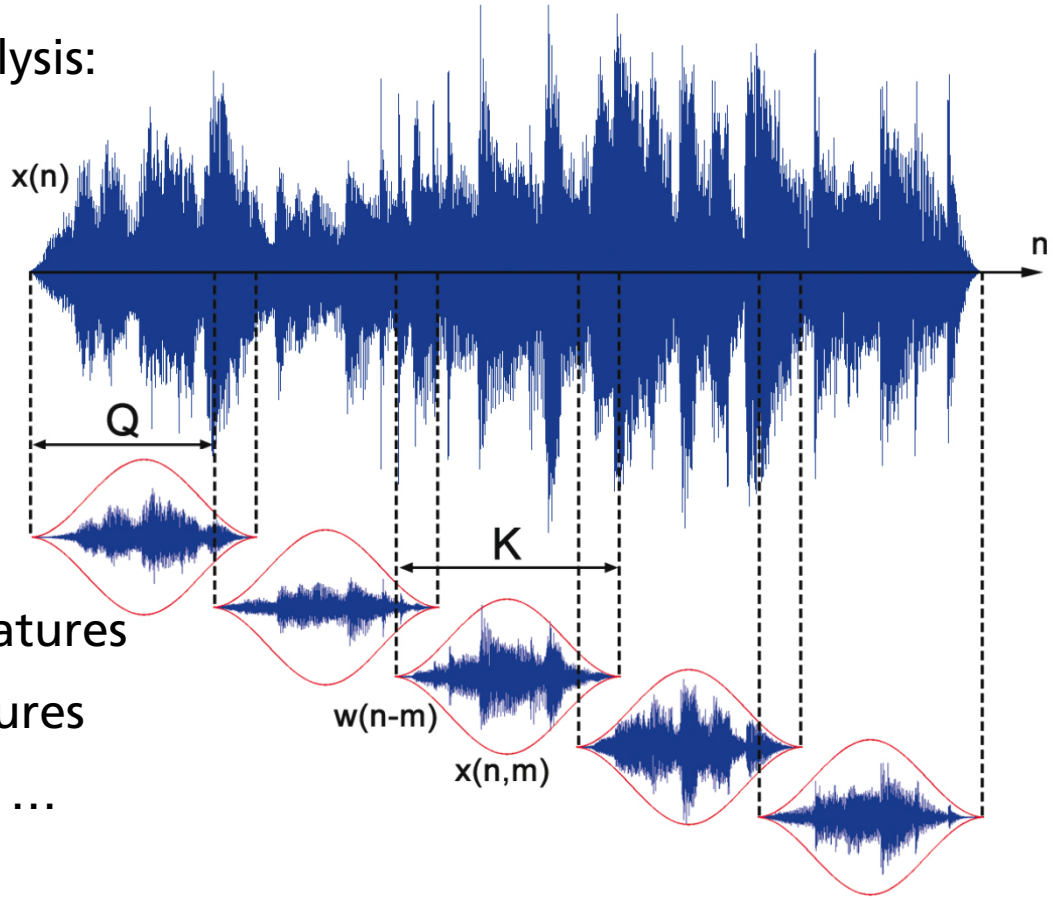
AUDIO FEATURES

- Low level
  - Signal derived, simple math
  - Sufficient for certain applications
  - Building blocks for more complex tasks
- Mid level
  - May already have semantic meaning
  - Combined or derived from low level features
- High level
  - Could be called “output parameters”
  - Can be understood by a human listener

AUDIO FEATURES: LOW-LEVEL FEATURE EXTRACTION

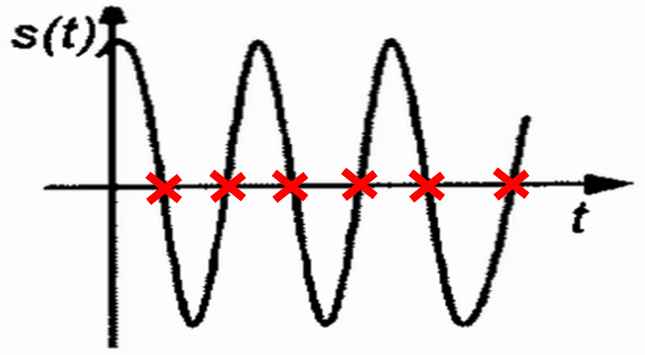
- Principle of short-term analysis:
  - Q: Hop-size
  - K: Window-/Block-size
  - w: Window-function
  - x: Signal frame

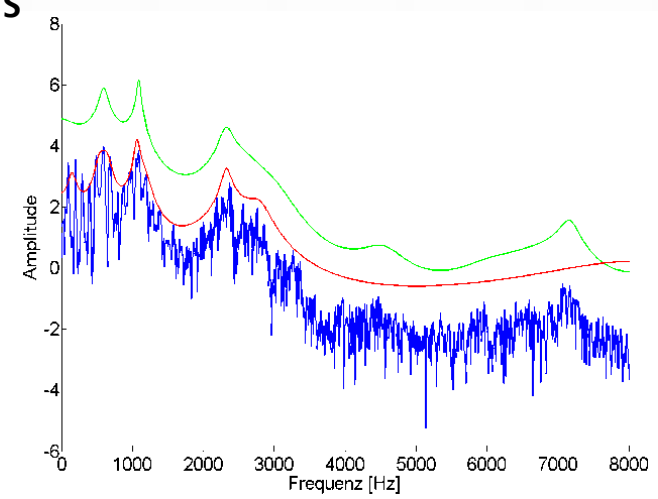


- In each analysis frame:
  - Time signal based LL features
  - Spectrum based LL features
  - Cepstrum based, others …

AUDIO FEATURES: LOW-LEVEL FEATURE EXTRACTION

- Time signal based LL features:
  - ZCR (Zero Crossing Rate): number of sign changes of the audio waveform per time frame → can be used to distinguish between low-pitched and high-pitched sounds, less suited for mixtures of multiple sounds
  - LPC (Linear Prediction Coefficients): compute filter coefficients, whose impulse response is as close to the spectral envelopes of the input signal as possible → originally used for speech coding





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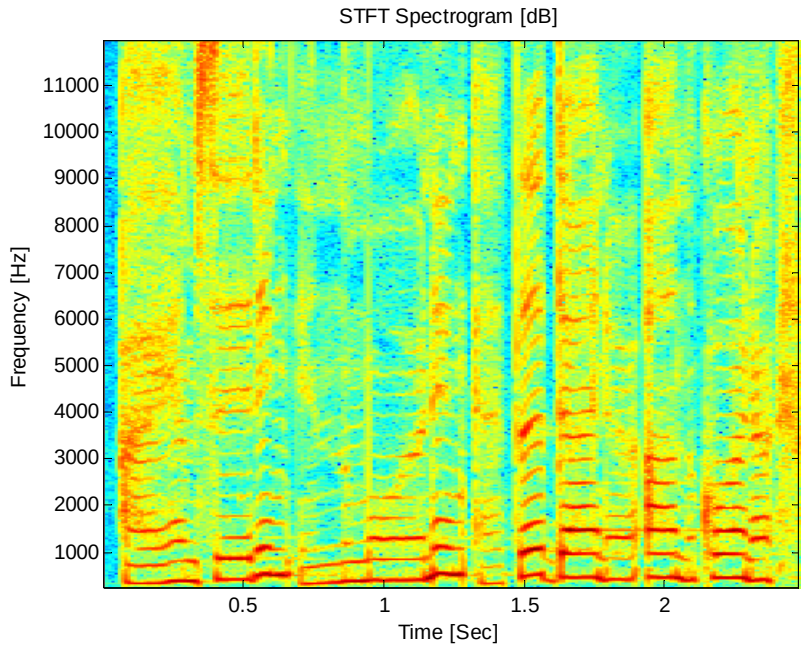
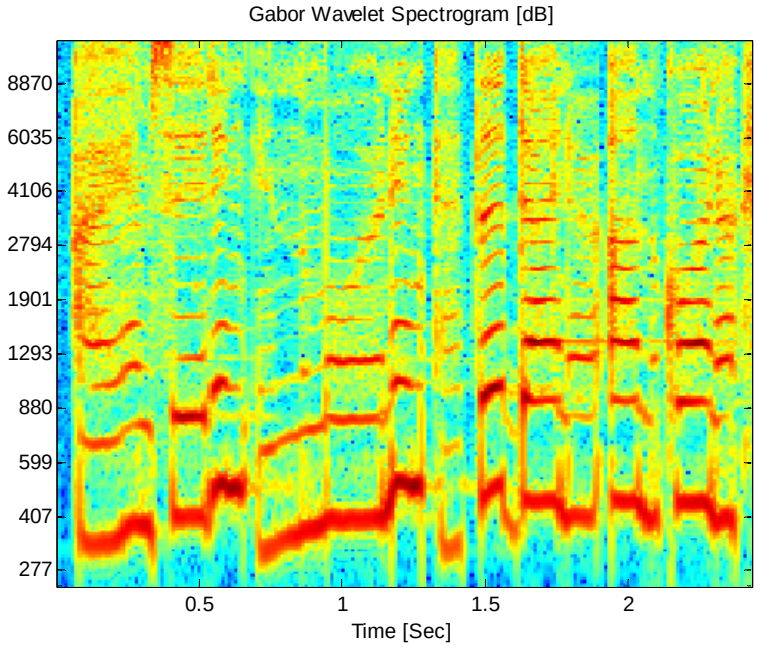
AUDIO FEATURES: LOW-LEVEL FEATURE EXTRACTION

- Spectrum-based features:
  - Spectrogram → Duality between time and frequency resolution
  - Linear vs. Logarithmic frequency axis





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MUSIC PLAGIARISM ANALYSIS: MOTIVATION

- Plagiarism is know since ancient times:

  The word „plagiarius“ was used for somebody kidnapping poems.

- In legal terms, different types of music plagiarism are discerned:
  - Unconscious plagiarism → The Chiffons vs. George Harrison example
  - Parallel creation → two authors create a work independently
  - Adaption → editing extensive enough to create new work
  - Free usage → original material must not be recognizable in derived one

MUSIC PLAGIARISM ANALYSIS: MOTIVATION

- Music Plagiarism:
  - Melody sequences
  - Rhythm patterns
  - Chord sequences

  } Similarities on a semantic level

- Sampling Plagiarism:
  - Re-use of existing recordings into a new work
  - Timbre qualities → Similarity on a signal level

- There are web-communities that search & document such cases

  (www.whosampled.com; www.the-breaks.com; www.secondhandsongs.com)

MUSIC PLAGIARISM ANALYSIS: MELODY PLAGIARISM

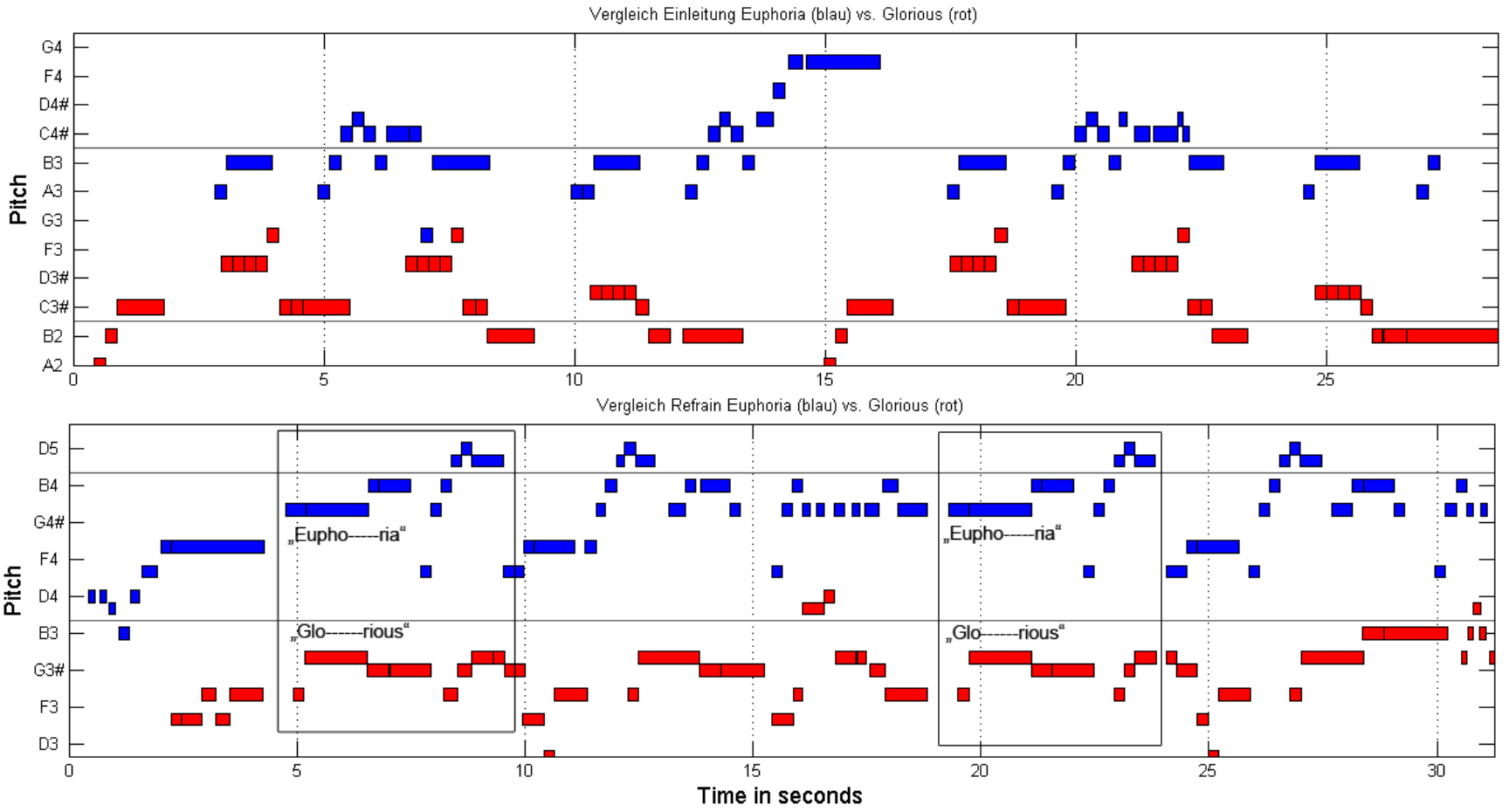
- Allegations of music plagiarism against the German entry to the European Song Contest

- Frontpage in biggest German newspaper Bild-Zeitung on 17.02.2013
  - Based on expertise by phonetician from University Kiel
  - Public broadcaster NDR commisioned musicologist expertise by Matthias Pogoda → result published 25.02.2013

- Sample „Loreen - Euphoria“
  - Tempo 131 BPM, Key F#-Minor

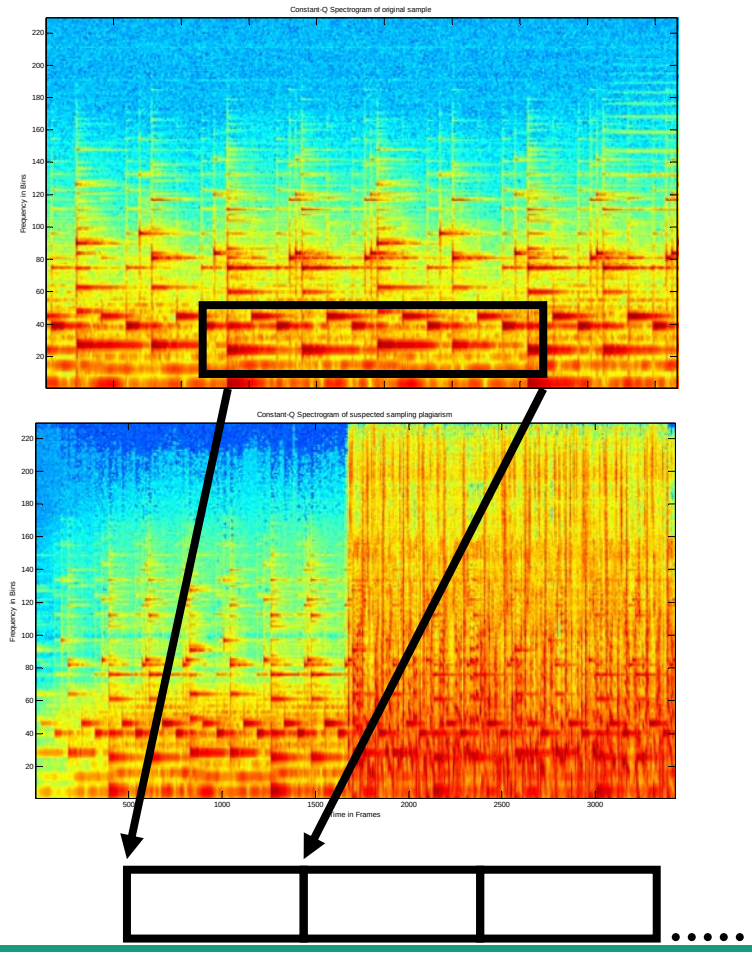
- Sample „Cascada - Glorious“
  - Tempo 128 BPM, Key G-Minor

MUSIC PLAGIARISM ANALYSIS: MELODY PLAGIARISM



SAMPLING PLAGIARISM

- Known data:
  - Original music excerpt
  - Suspected sampling plagiarism
- Edit operations:
  - Cropping
  - Looping
  - Time-stretching
  - Pitch-shifting
  - Mixing of new instruments



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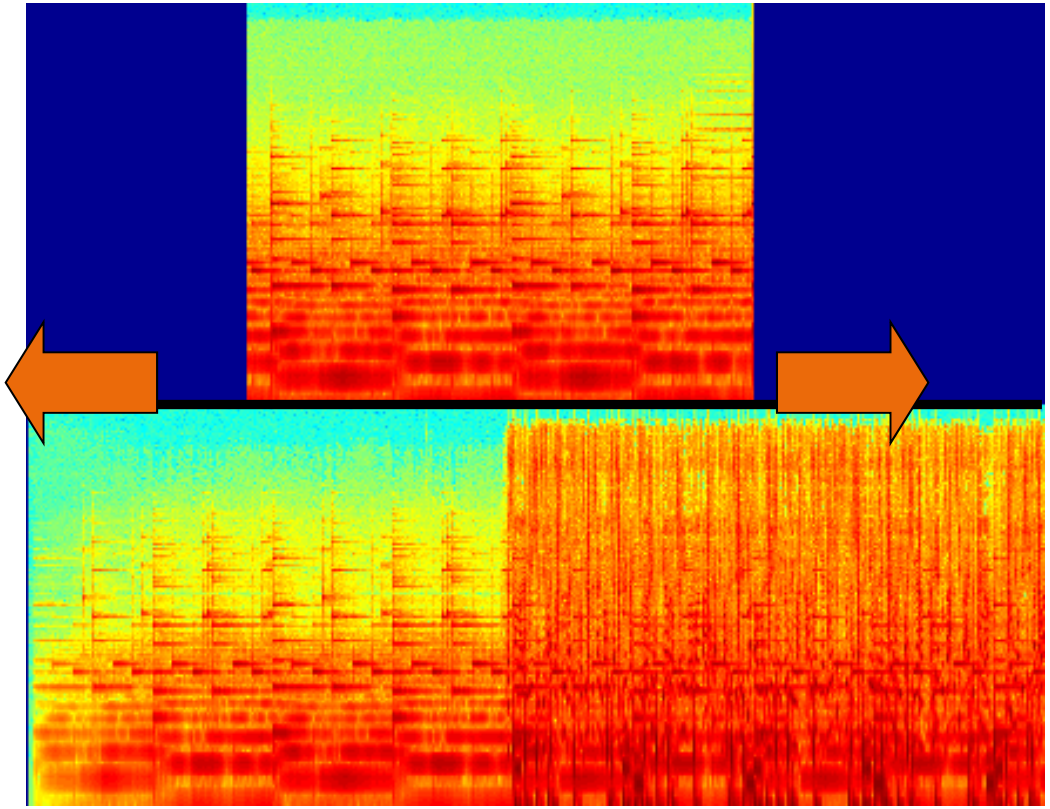
SAMPLING PLAGIARISM: BRUTE FORCE APPROACH

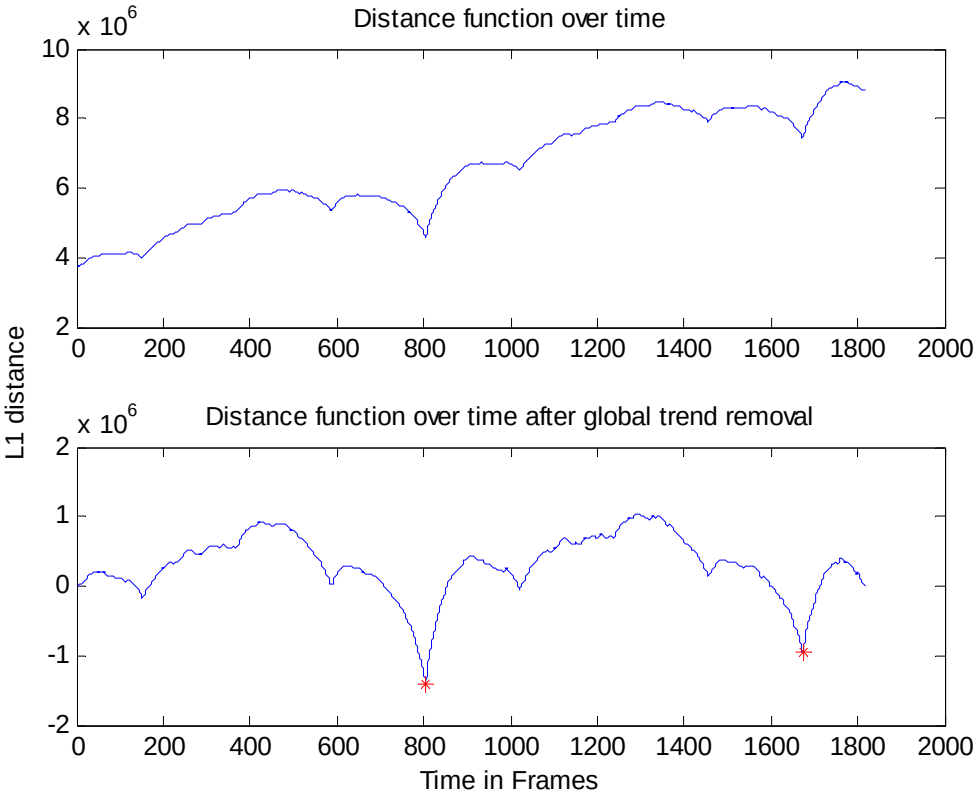
- Shift original along suspected plagiarism → find best match

- Distance measures: L1 distance, L2 distance, Correlation …



SAMPLING PLAGIARISM: BRUTE FORCE APPROACH

- Restrict search space by preliminary beat estimation
- only test timestretching factors at reasonable multiples of the beat
- only compare frame by frame around beat positions



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DETECTING EDITING OR OTHER TAMPERING

- Watermarking:
  - Insert inaudible signals into the music / speech
  - Tradeoff between
    - Bitrate
    - Robustness
    - Inaudibility of the watermark
  - Can survive some modification of the signal (even transmission from loudspeaker to microphone) or can be fragile on purpose
  - Often does not survive heavier modifications
  - Clearly a forensic tool, it is often not known that a watermark has been applied

DETECTING EDITING OR OTHER TAMPERING

- Digital Signatures
  - Not part of the signal: may be deleted
  - Additional data necessary
  - Can implement a “bind identity to the content”
  - Can easily be stripped from the main data

- Tampering detection without any additional signal:
  - Find discontinuities in the speech signal
  - E.g. in the phase of Electric Network Frequency (ENF) signals

PHASE ANALYSIS

- Idea:
  - Modifications cause changes in the ENF phase
  - Using this changes to detect tamperings
  - Works without any reference data

- Approach
  - Extraction phase from ENF
  - Detection discontinuities
  - Segmentation of recording

WANT TO LEARN MORE?

Visit WASP workshop this Friday 20.09.2013 (RoomF 413)

- 11:00 - 12:30 Session 2 / 4

  Sebastian Mann: Combining ENF Phase Discontinuity Checking and Temporal Pattern Matching for Audio Tampering Detection

- 13:30 – 14:45 Session 3 / 4 (Posters)

  Christian Dittmar: Estimating MP3PRO Encoder Parameters From Decoded Audio

CONCLUSIONS:

- More and more people are concerned about privacy and security:
  - We need to do more about these topics
  - We do have technical means to help
- In the audio world:
  There are several methods to help against unwanted tampering:
  - Identification of plagiarism
  - Identification of changes to a signal
- Authentication is a topic which deserves more attention