Content-Based Audio Management

Music Information Retrieval

Jake Atwell, Philip Jakob

Agenda

- Einleitung/Motivation
- Muscle Fish Verfahren
- Baum-Verfahren
- Vergleich
- Fazit

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- **Einleitung/Motivation**
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Einleitung

- Aktuelle Methoden für Audiosuche
  - subjektives Text
- Inhaltsbasiertes suchen und vergleichen
  - Die Signal selbst analysieren
  - PCA, RCA, Tempo-based, CLAS
- Mögliche Klassifizierungen
  - Simile
    - bellende Hunde
  - Akustische Eigenschaften
    - Helligkeit, Lautheit, Tonhöhe, usw.
  - Subjektive Eigenschaften
    - entspannt, aggressiv, usw.
  - Onomatopöie
    - BAM!

Einleitung

Signal

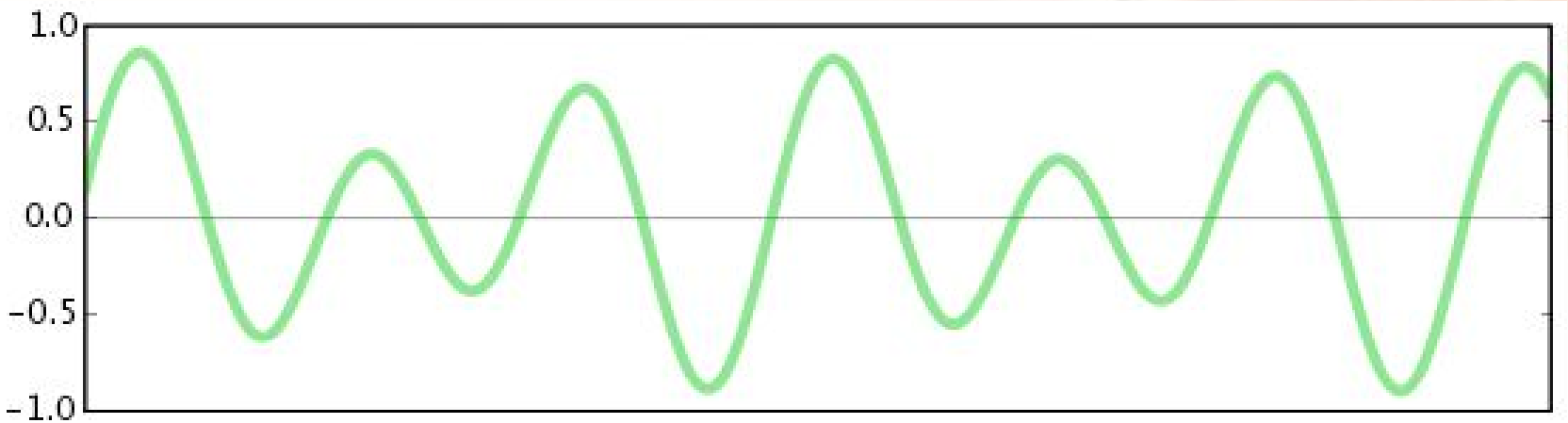

Image adapted from
http://manual.audacityteam.org/man/digital_audio.html

Einleitung

Signal

Samplingrate

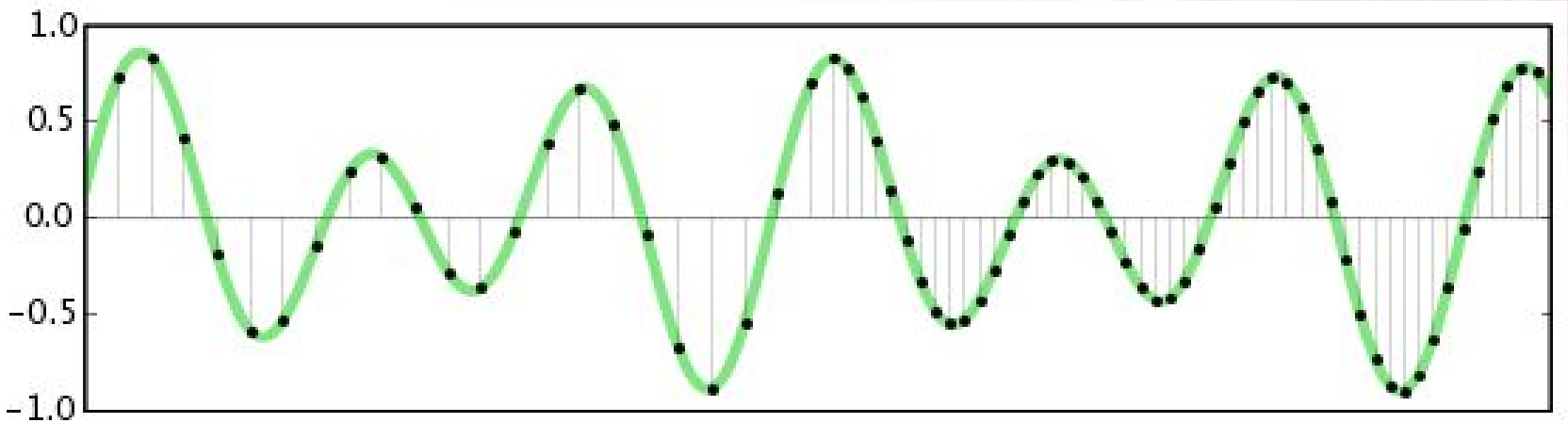

Image adapted from
http://manual.audacityteam.org/man/digital_audio.html

Einleitung

Signal Samplingrate Samplingstiefe

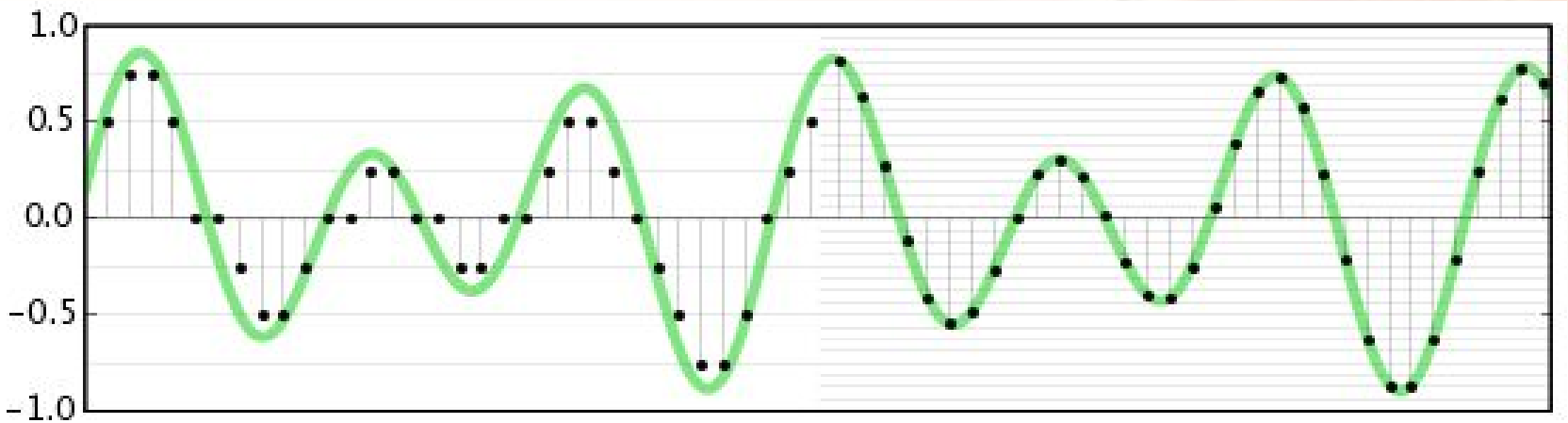

Image adapted from
http://manual.audacityteam.org/man/digital_audio.html

Motivation: Anwendungen

Audio Editor

Ohne?

- Klicken und Abspiele

Mit?

- Bestimmten Eigenschaften können markiert werden
  - Solos, Applaus, Reden, usw.

Sicherheitsdienste

Ohne?

- Hinschauen/hören und warten
- Monotones Arbeit lässt sich gut automatisieren

Mit?

- Gefährliche Geräusche “lernen”

Ton Synthese

Ohne?

- Töne erzeugen und hinhören

Mit?

- Töne erzeugen und vergleichen anhand klar definierten Eigenschaften

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Muscle Fish

Generelles Paradigma

1. Genauen Zahlen in einer Ausschnitt
2. Fuzzy search
3. Objektive und subjektive Eigenschaften
4. Musikalischer bzw. sprachlicher Inhalt

Muscle Fish

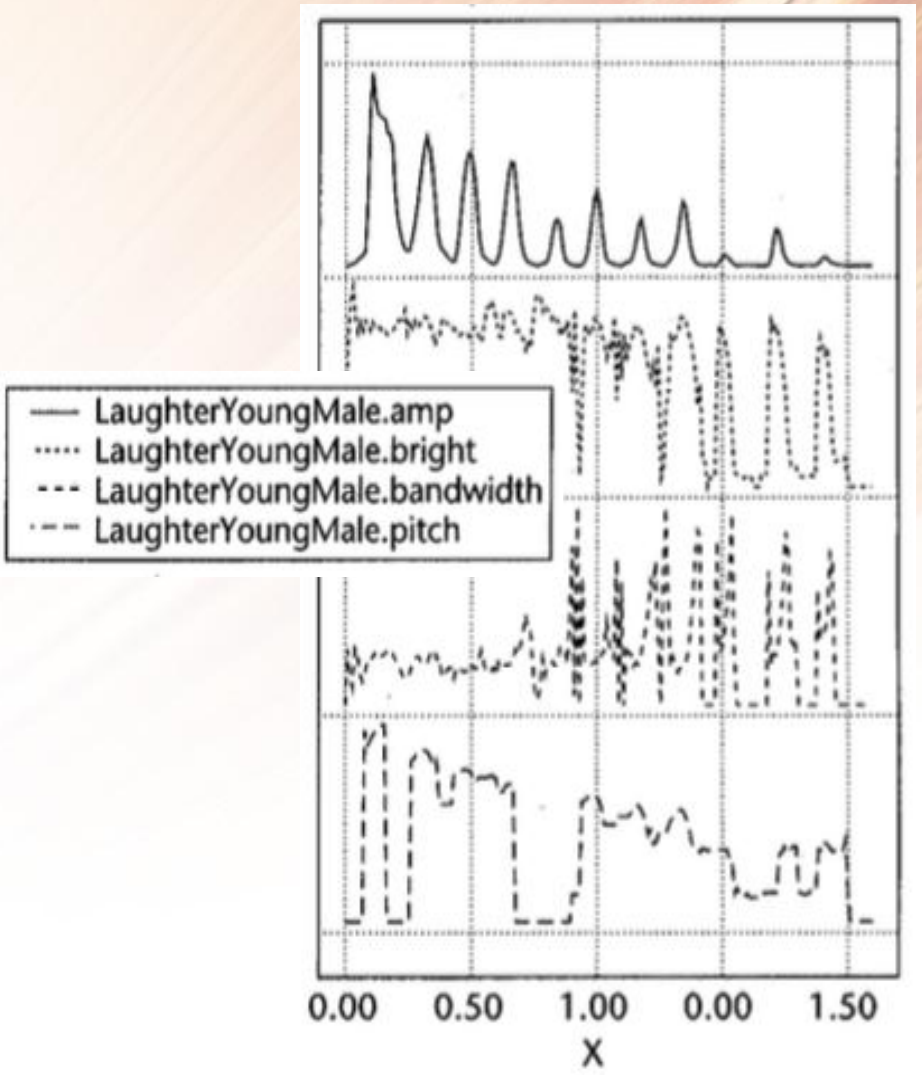
Relevanter Eigenschaften

- Lautheit
  - RMS von Signal
- Tonhöhe
  - Größter gemeinsamer Teiler
- Helligkeit
  - Menge an höheren Frequenzen
- Bandbreite
  - wie viele Frequenzen in der Signal sind
- Harmonizität
  - wie “harmonisch” ein Ton ist

Muscle Fish

Charakterisierung eines Signals

- N-dimensionaler Vektor
  - Mittelwert
  - Varianz
  - Autokorrelation für eine kleine Zeitverschiebung
  - mit der Lautheit gewichtet
- Klassen erstellen
- Töne zuordnen



Adapted from Wold, Erling, et al. "Content-based classification, search, and retrieval of audio."

Muscle Fish

Datenbankeintrag

Analysis feature vector
- Duration
- Pitch [mean, variance, autocorrelation]
- Amplitude [mean, variance, autocorrelation]
- Brightness [mean, variance, autocorrelation]
- Bandwidth [mean, variance, autocorrelation]

Sound file attributes
- File name
- Sample rate
- Sample size
- Sound file format
- Number of channels
- Creation date
- Analysis date

User attributes
- Keywords
- Comments

Klassen erstellen

- Mittelwert und Covarianz Vektoren/Matrizen

$$\mu = (1/M) \sum_j a[j]$$

$$R = (1/M) \sum_j (a[j] - \mu) \cdot (a[j] - \mu)^T$$

Property	Mean	Variance	Autocorrelation
Loudness	−54.4112	221.451	0.938929
Pitch	4.21221	0.151228	0.524042
Brightness	5.78007	0.0817046	0.690073
Bandwidth	0.272099	0.0169697	0.519198

Adapted from Wold, Erling, et al. "Content-based classification, search, and retrieval of audio."

Muscle Fish

Töne zuordnen

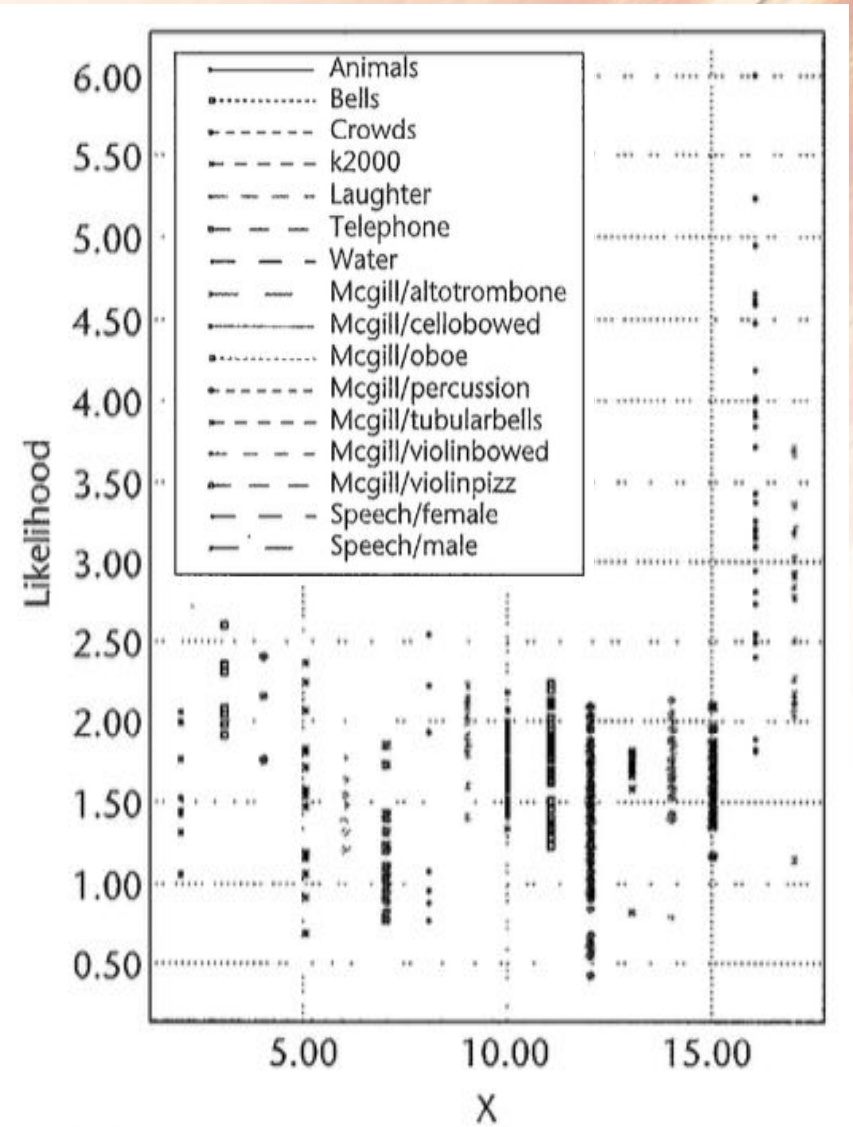
- Gewichteter Euklidischer Abstand

$$D = ((a-\mu)^T R^{-1} (a-\mu))^{1/2}$$

- Likelihood nach der Normalverteilung

$$L = exp(-D^2/2)$$

- “Tear gas” Beispiel



Adapted from Wold, Erling, et al. "Content-based classification, search, and retrieval of audio."

Muscle Fish

- Ob-/Subjektive Eigenschaften
- Statistisches Verfarhen
- Werden durch Vektoren/Abstände beschreiben/verglichen

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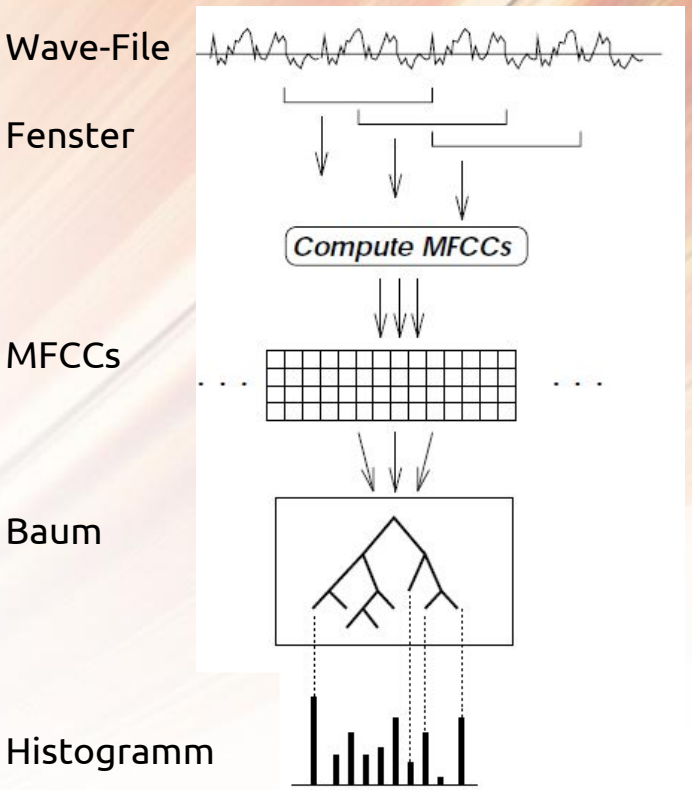
Baum-Verfahren

Rein datenorientierter Ansatz

Idee: Gegeben eine (ggf. auch unbekannte) Audio-Datei - welche anderen bekannten Audio-Dateien sind ähnlich

Frage: Wie definiert man Ähnlichkeit bei Audiodateien?



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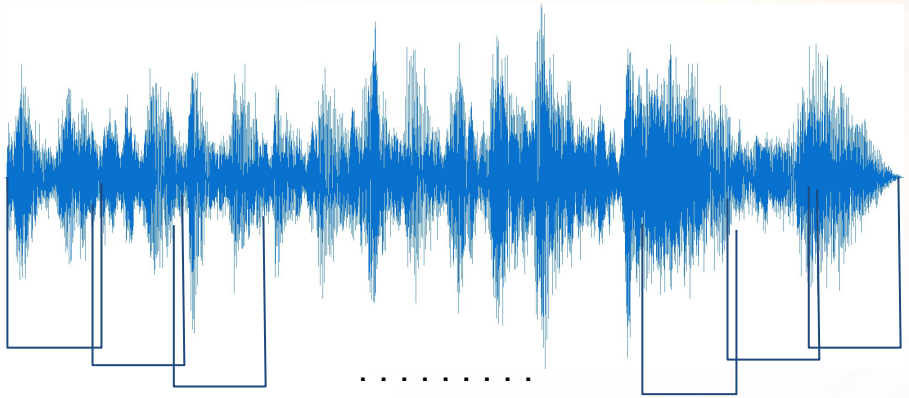
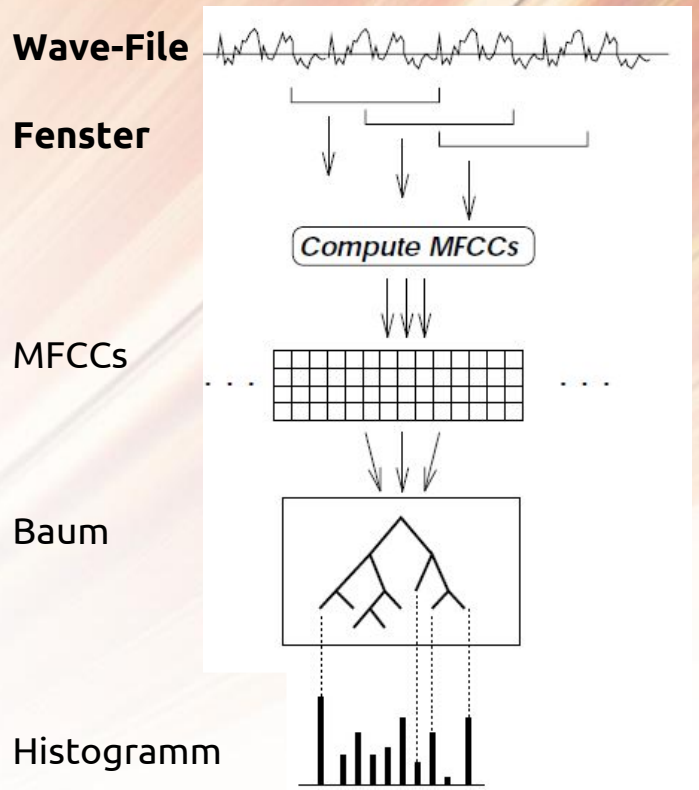
Baum-Verfahren

Waveform Audio File Format (WAVE/WAV)





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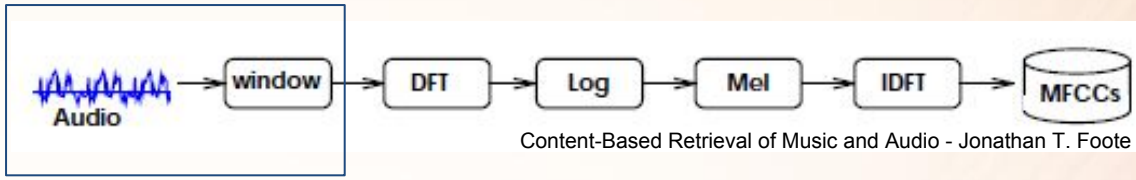
<u>Gängige Parameter:</u>
Fenstergröße: 25ms
Überschneidung: 10ms

Baum-Verfahren



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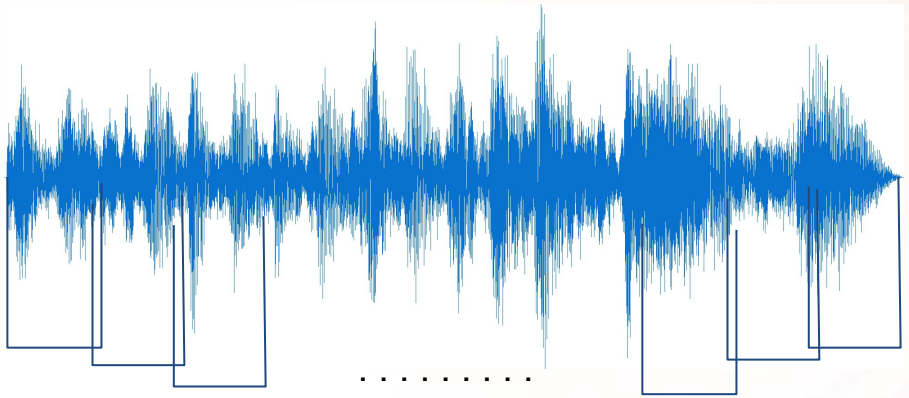
Waveform Audio File Format (WAVE/WAV)



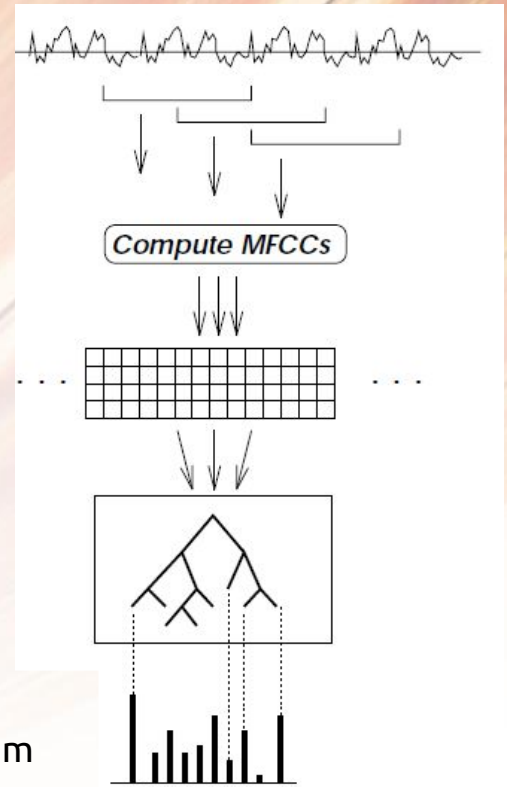
Wave-File

Fenster

MFCCs

Baum

Histogramm



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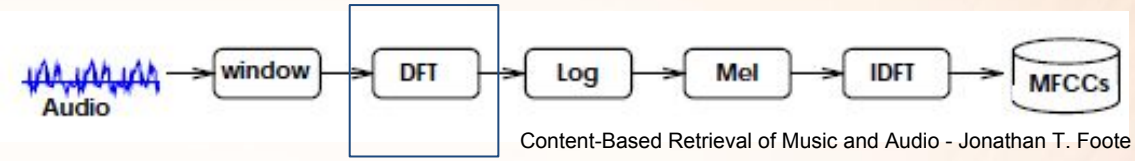
Mel **F**requency **C**epstral **C**oefficients

Baum-Verfahren



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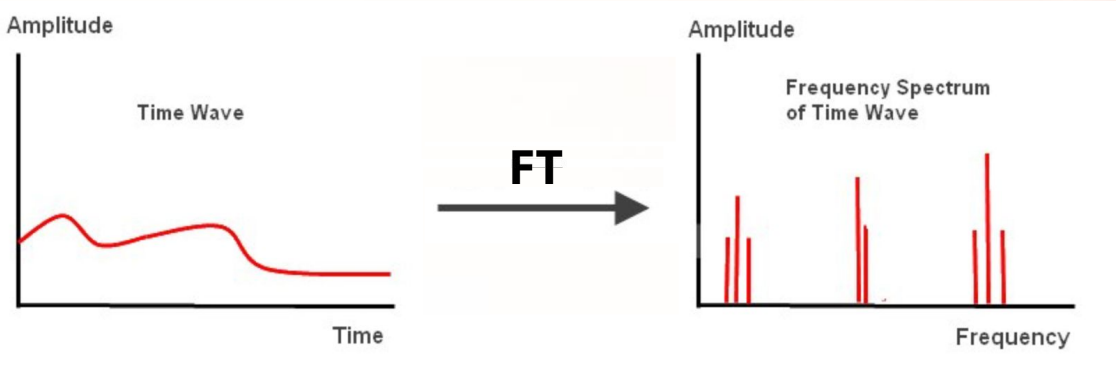

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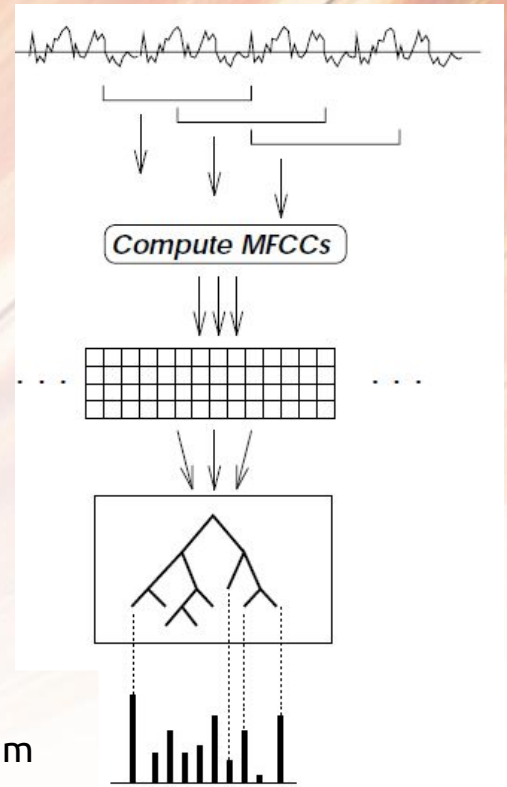
Wave-File

Fenster

MFCCs

Baum

Histogramm



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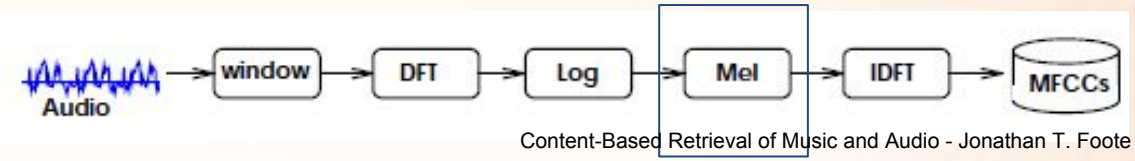

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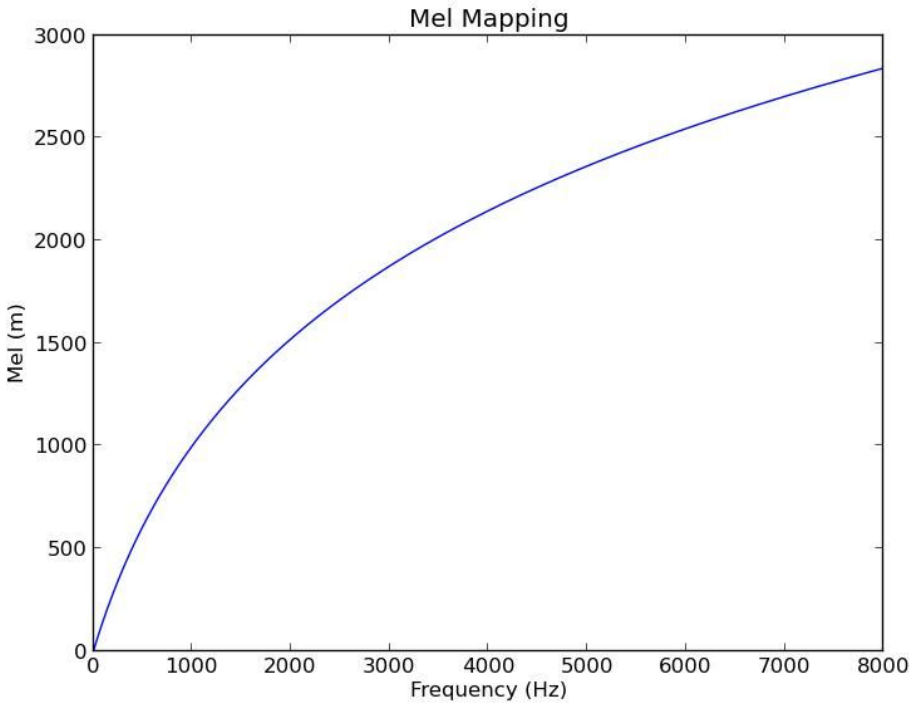

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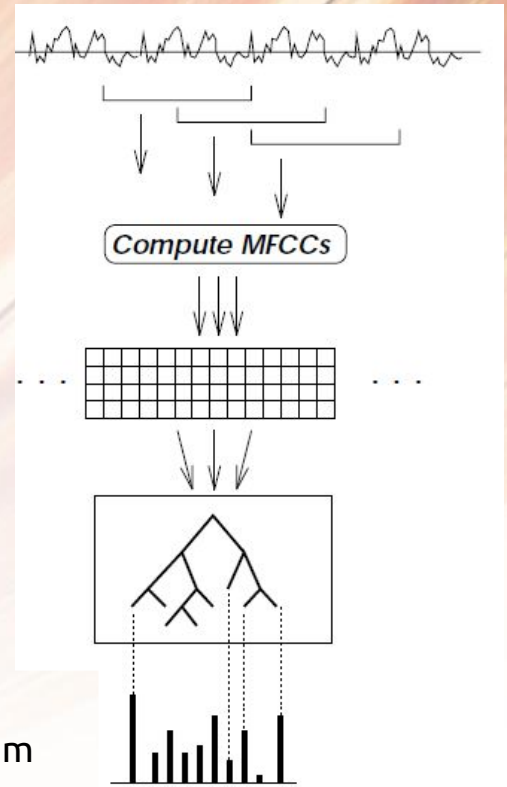
Wave-File

Fenster

MFCCs

Baum

Histogramm



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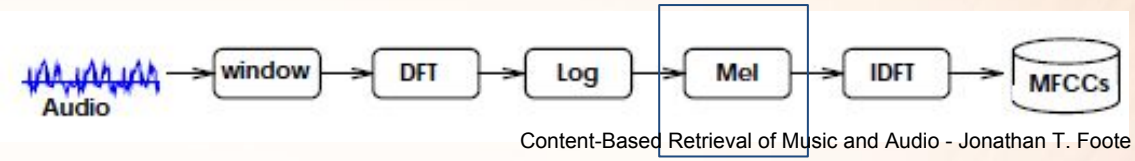

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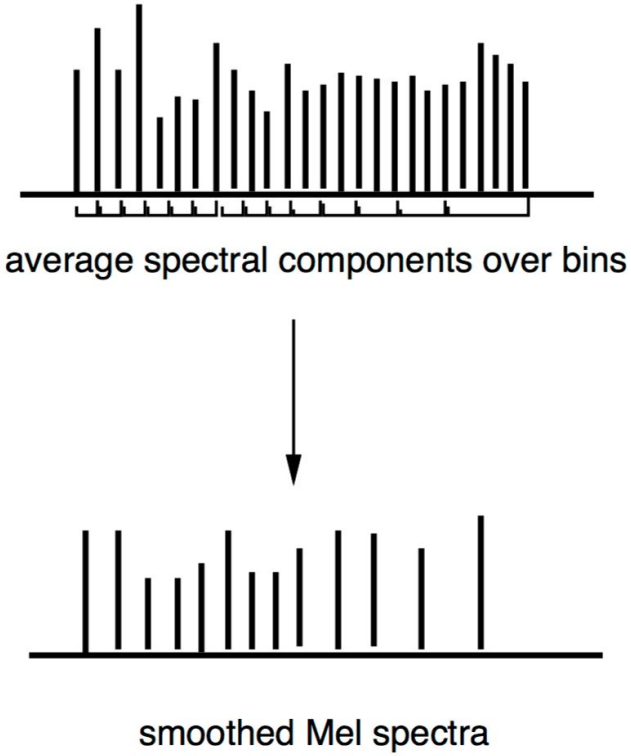
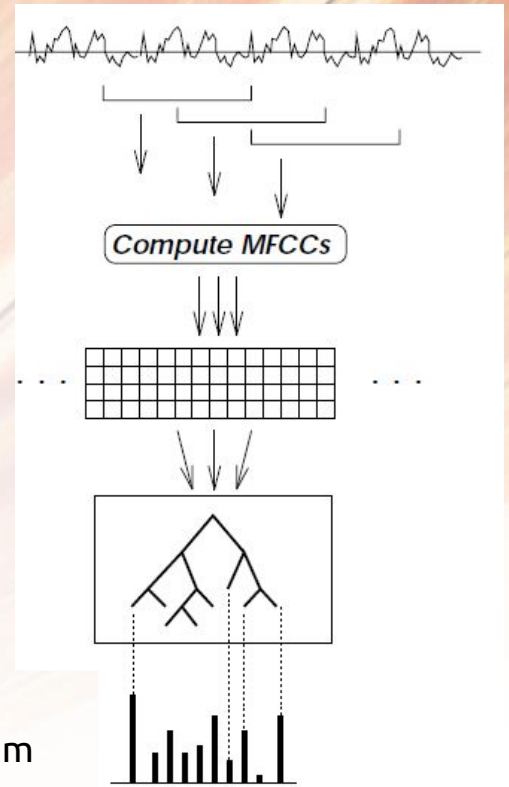


mel frequency cepstral coefficients for music modeling - Beth Logan



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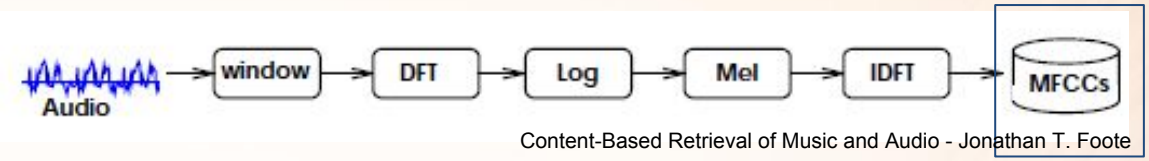

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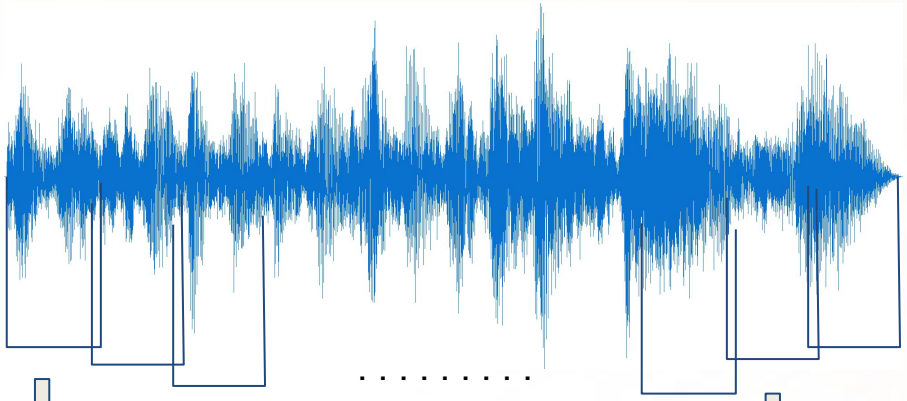
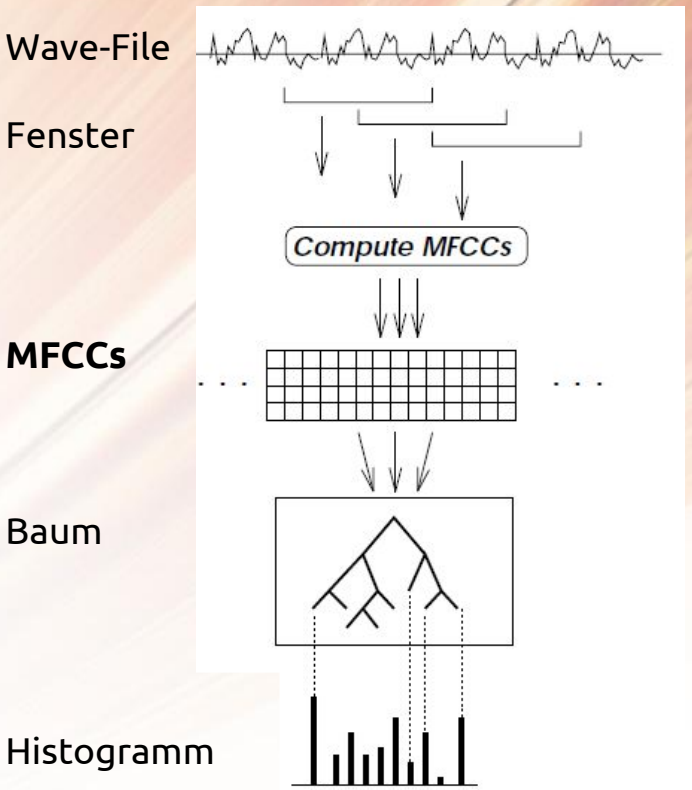
Ergebnis:

- Kompakte Darstellung des Frequenzspektrums mit festgelegter Anzahl an Parametern



$$\begin{pmatrix} a_{11} \\ a_{21} \\ \vdots \\ a_{n1} \end{pmatrix}, \quad \begin{pmatrix} a_{1\,(n-1)} \\ a_{2\,(n-1)} \\ \vdots \\ a_{n\,(n-1)} \end{pmatrix}$$



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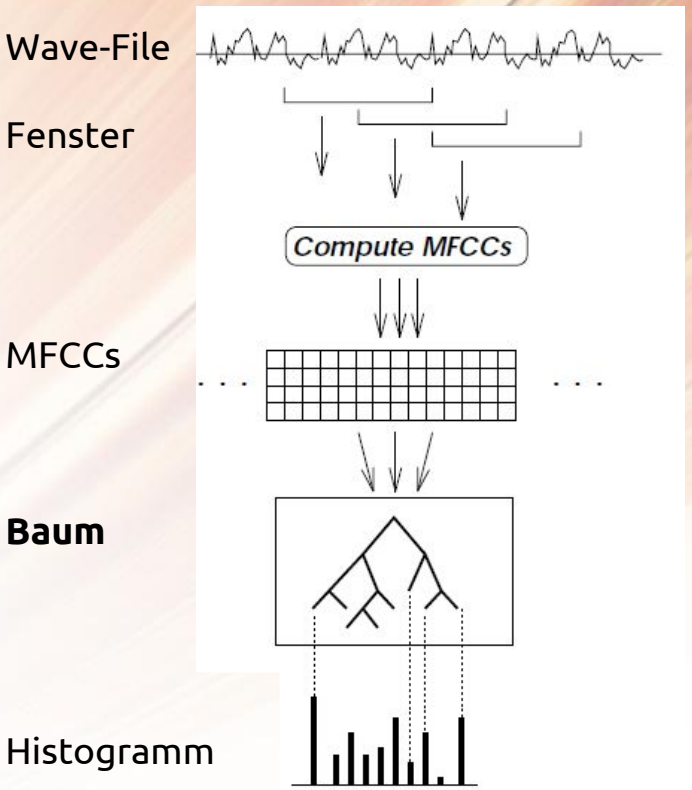
Baum-Verfahren

- Trainingsdaten klassifiziert
- Supervised Algorithmus
- Ziel: Wahrscheinlichkeit in Blättern maximieren



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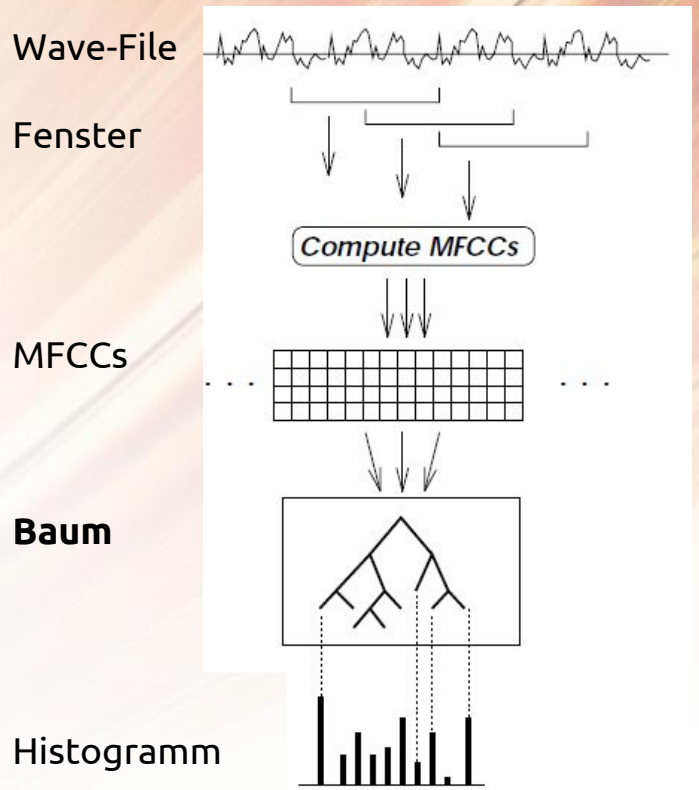
Baum-Verfahren

Classification Trees

Outlook	Temp (°F)	Humidity (%)	Windy?	Class
Sunny	75	70	True	Play tennis
Sunny	80	90	True	Don't play
Sunny	85	85	False	Don't play
Sunny	72	95	False	Don't play
Sunny	69	70	False	Play tennis
Overcast	72	90	True	Play tennis
Overcast	83	78	False	Play tennis
Overcast	64	65	True	Play tennis
Overcast	81	75	False	Play tennis
Rain	71	80	True	Don't play
Rain	65	70	True	Don't play
Rain	75	80	False	Play tennis
Rain	68	80	False	Play tennis
Rain	70	96	False	Play tennis



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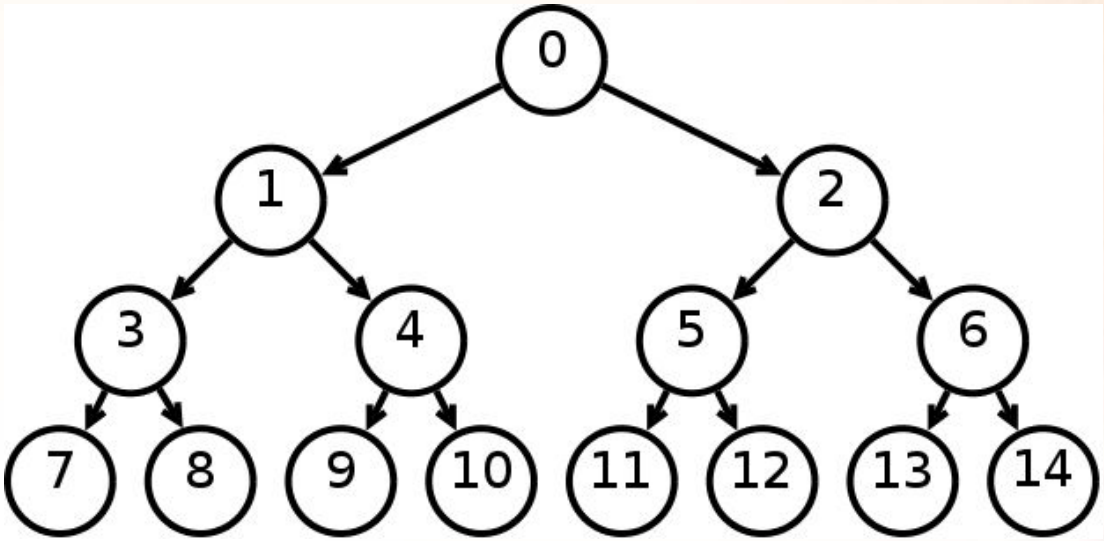

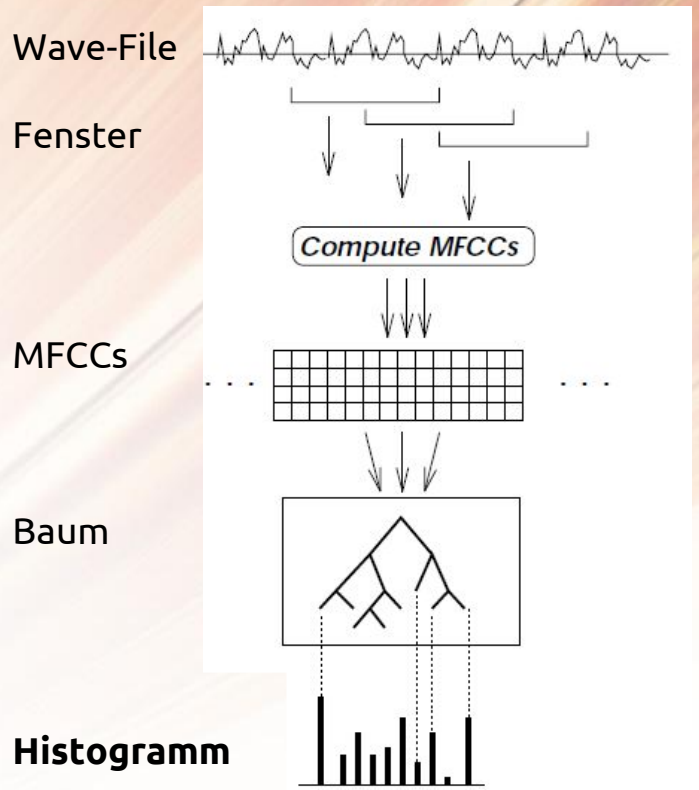

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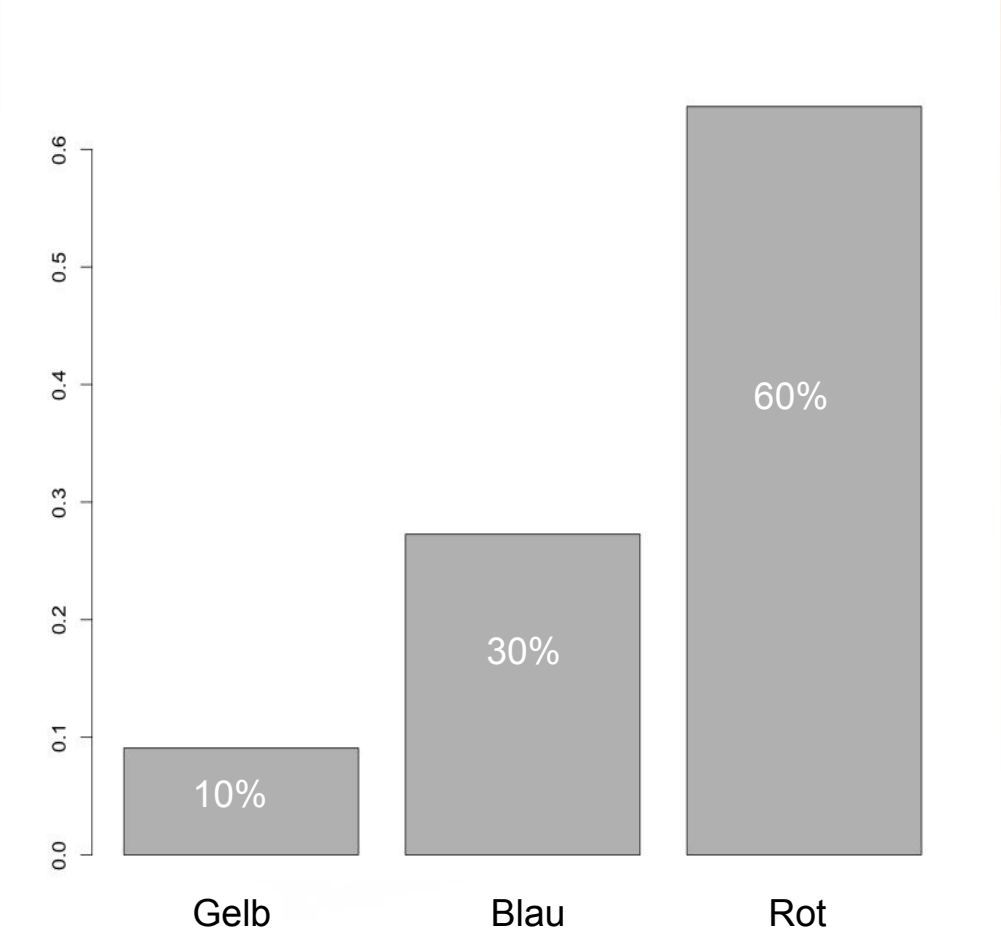

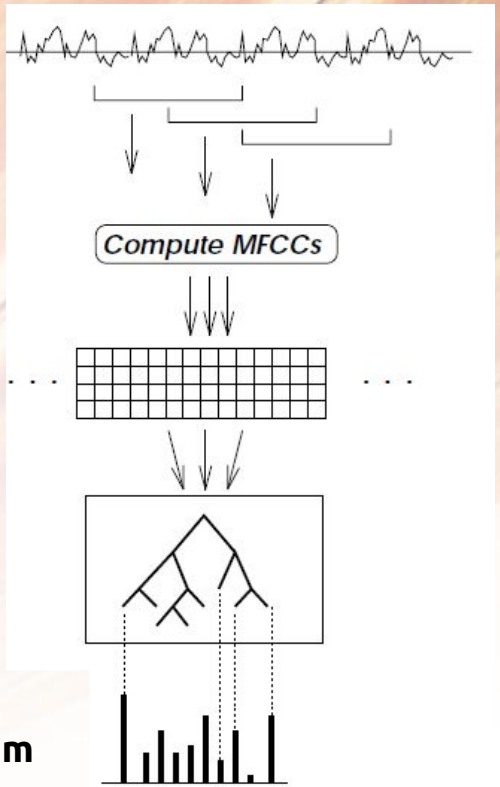

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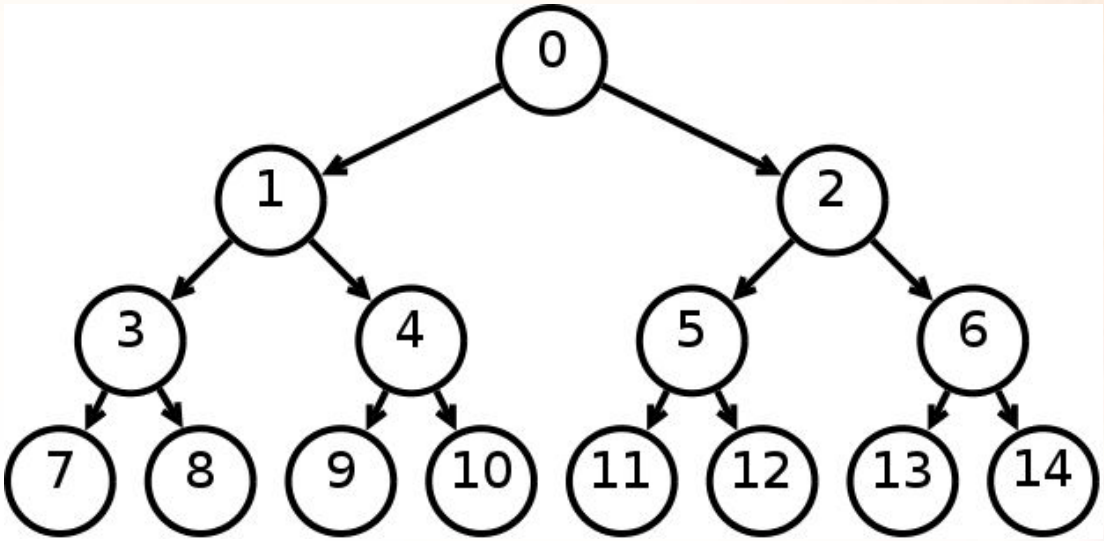

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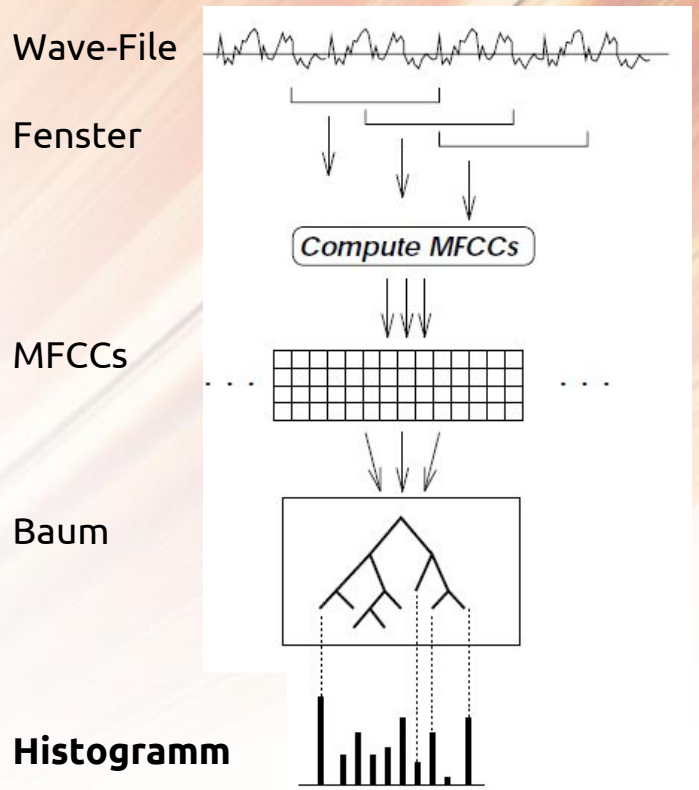

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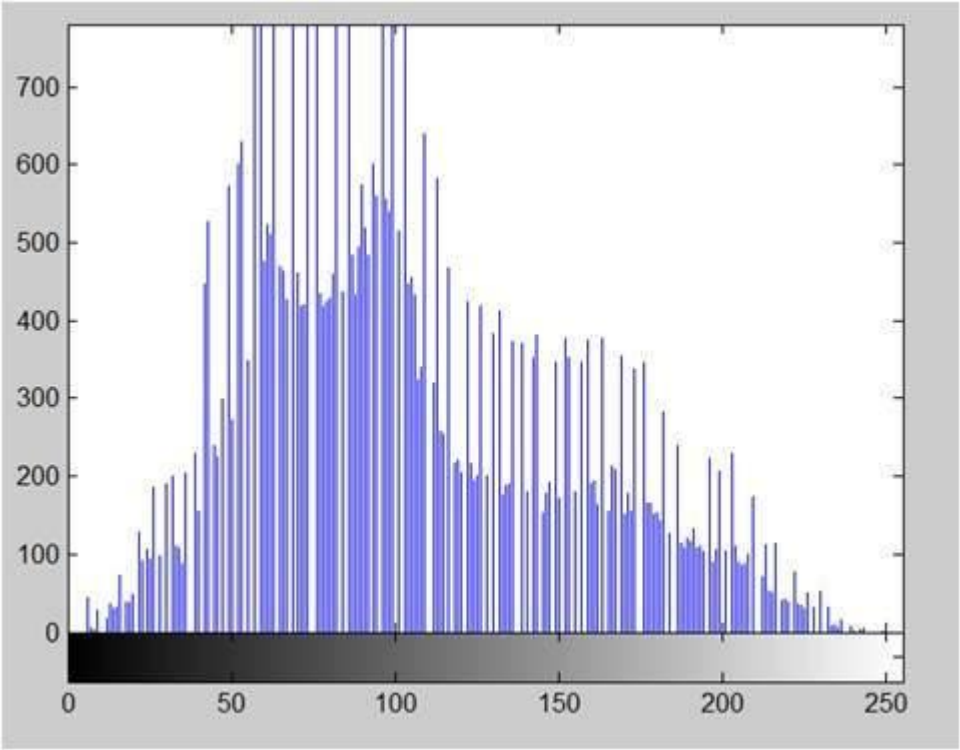

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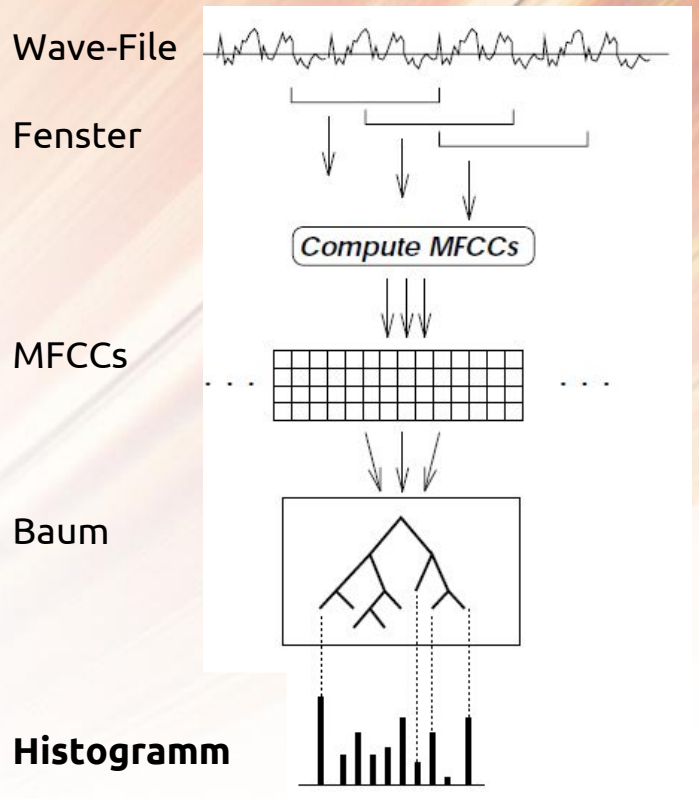

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Baum-Verfahren

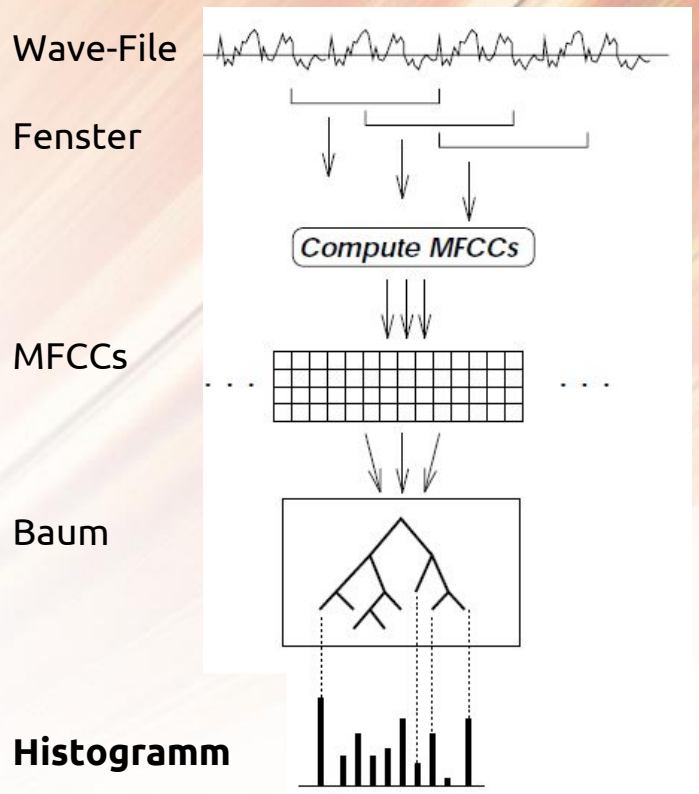
Eingangsfrage:
Wann sind zwei Audiosignale ähnlich?

Antwort:
Wenn ihre Histogramme ähnlich sind!

Neue Frage:
Wie wird die Ähnlichkeit von Histogrammen definiert?

Antwort:
Euklidischer Abstand!

$$\sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$



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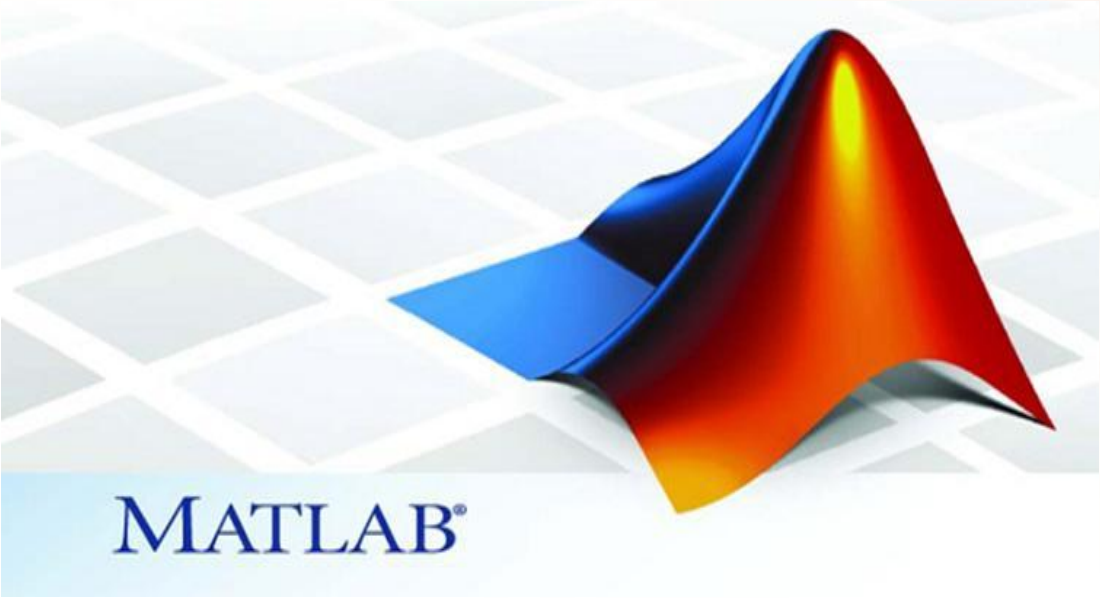
Demo



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Agenda

- Einleitung/Motivation
- Muscle Fish Verfahren
- Baum-Verfahren
- **Vergleich**
- Fazit

Vergleich

- Test mit 409 Audiodateien
- “Supervektoren” mit 65 Features (5 * 13)
- Supervised: 41 Klassen (Oboe, ..)

Distance	Q Tree (D_C) “unsupervised”	Q Tree (D_C) supervised	Muscle Fish (no DPL)	Muscle Fish (+ DPL)
Laughter (M)	0.68	0.82	1.00	1.00
Oboe	0.11	0.43	0.69	0.94
Agogo	1.00	1.00	0.53	0.58
Speech (F)	0.77	0.87	0.69	0.94
Touchtone	0.61	1.00	0.44	0.73
Rain/thunder	0.22	0.35	0.30	0.42
Mean AP	0.580	0.772	0.608	0.768

Content-Based Retrieval of Music and Audio = Jonathan T. Foote

Agenda

- Motivation/Einleitung
- Muscle Fish Verfahren
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- **Fazit**

Fazit

- Es funktioniert.
- Ergebnisse / Modelle stark abhängig von den verwendeten Daten.
- Viele Parameter können Ergebnis beeinflussen.
- Unsupervised Algorithmen schon recht Präzise.

Quellen

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- Wold, Erling, et al. "Content-based classification, search, and retrieval of audio." *IEEE multimedia* 3.3 (1996): 27-36.
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