Musical Data Bases — Semantic-oriented Comparison of Symbolic Music Documents

Dipl.-Inf. Michael Rentzsch

Chemnitz University of Technology

Information Systems & Software Engineering

Informatiktag 2006
Content

- Project Musical Data Bases
- Approaches in Music Information Retrieval (MIR)
- Our approach: The Lead Sheet Model
- Results
- Further Development
Chair Data Management
Dr. Frank Seifert

Chair Information Systems & Software Engineering
Michael Rentzsch

Algorithms and Methods:
- Analysing music data
- Comparing music documents
- → Indexing in music data bases
Project Musical Data Bases

- **Chair Data Management**
  Dr. Frank Seifert

- **Chair Information Systems & Software Engineering**
  Michael Rentzsch

- **Algorithms and Methods:**
  - Analysing music data
  - **Comparing music documents**
  - → Indexing in music data bases
Existing Approaches

- **Symbolic representation**
  - Contour of Melody $\rightarrow$ Edit distance
  - “Musical” Edit-Distanz
    (Melody/Rhythm/Harmonisation)
  - Geometric Modelling

- **Sub-symbolic representation**
  - Audio Fingerprinting
  - Tone and harmony recognition $\rightarrow$
    Methods from symbolic representation
Existing Approaches

- **Symbolic representation**
  - Contour of Melody $\rightarrow$ Edit distance
  - “Musical” Edit-Distanz (Melody/Rhythm/Harmonisation)
  - Geometric Modelling

- **Sub-symbolic representation**
  - Audio Fingerprinting
  - Tone and harmony recognition $\rightarrow$ Methods from symbolic representation
Existing Approaches

- **Symbolic representation**
  - Contour of Melody → Edit distance
  - “Musical” Edit-Distanz (Melody/Rhythm/Harmonisation)
  - Geometric Modelling

- **Sub-symbolic representation**
  - Audio Fingerprinting
  - Tone and harmony recognition → Methods from symbolic representation
Critical Evaluation

- Fingerprinting: Original pieces (recordings) only
- Simple Edit distance: No musical background → based on statistics
- No degree of equality (motifs/patterns)
- No musical context
- No comparison of entire pieces of music

Alternatives are required
- Knowledge about musical context
- Equality of music documents
Critical Evaluation

- Fingerprinting: Original pieces (recordings) only
- Simple Edit distance: No musical background → based on statistics
- No degree of equality (motifs/patterns)
- No musical context
- No comparison of entire pieces of music

Alternatives are required

- Knowledge about musical context
- Equality of music documents
PhD-Thesis “Musikalische Datenbanken – Grundlagen semantischer Indexierung von Tondokumenten”

Basic idea: characteristic motif (CM)
- ≈ Musical pattern
- Melody
- Rhythm
- Tempo
- Harmonisation

\[ \text{\[F \ C7\] with \[44\] beats per minute} \]

\[ \text{\[\begin{array}{c}
    \text{F} \\
    \text{C7}
\end{array}\]} \]
Term lead sheet from jazz and pop music

- Adds structural and semantic (relation) aspect to model
- Modelling as a graph
Lead Sheet Templates

1. Starting point: Original piece (e.g. traditional)
2. Finding characteristic motifs → \( \{ CM_i \} \)
3. Analysing “semantic” context → template
1. Starting point: Original piece (e.g. traditional)
2. Finding characteristic motifs $\rightarrow \{CM_i\}$
3. Analysing “semantic” context $\rightarrow$ template

Dipl.-Inf. Michael Rentzsch  Musical Data Bases
Lead Sheet Templates

1. Starting point: Original piece (e.g. traditional)
2. Finding characteristic motifs $\rightarrow \{CM_i\}$
3. Analysing “semantic” context $\rightarrow$ template

Diagram:

- $LS_{AME}$
- $CM_1$
- $CM_2$
- $CM_3$
- $CM_4$
Central Idea

Every piece of music can be represented as a template using the identified motifs and the information in the lead sheet graph.

Thus, comparing two pieces of music can be reduced to comparing these templates.

Requires

- Methods to identify motifs (paying tribute to small variations)
- Distance metric for lead sheet templates
Central Idea

Every piece of music can be represented as a template using the identified motifs and the information in the lead sheet graph.

Thus, comparing two pieces of music can be reduced to comparing these templates.

Requires

- Methods to identify motifs (paying tribute to small variations)
- Distance metric for lead sheet templates
Equality function for motifs (1/2)

Comparing 4 parameters of music:
- Melody
- Rhythm
- Tempo
- Harmonisation
- Voice

5 degrees of equality:
\[ E_M, E_R, E_T, E_H, E_V \in [0 \ldots 1] \]

Weighting of parameters \( W_p \)
Equality function for motifs (1/2)

Comparing 4 parameters of music:
- Melody
- Rhythm
- Tempo
- Harmonisation
- Voice

5 degrees of equality:
\[ E_M, E_R, E_T, E_H, E_V \in [0 \ldots 1] \]

Weighting of parameters \( W_p \)
Equality function for motifs (1/2)

Comparing 4 parameters of music:
- Melody
- Rhythm
- Tempo
- Harmonisation
- Voice

5 degrees of equality:
\[ E_M, E_R, E_T, E_H, E_V \in [0 \ldots 1] \]

Weighting of parameters \( W_p \)
Equality function for motifs (1/2)

Comparing 4 parameters of music:
- Melody
- Rhythm
- Tempo
- Harmonisation
- Voice

5 degrees of equality:
\[ E_M, E_R, E_T, E_H, E_V \in [0 \ldots 1] \]

Weighting of parameters \( W_p \)
Comparing 4 parameters of music:
- Melody
- Rhythm
- Tempo
- Harmonisation
- Voice

5 degrees of equality:
\[ E_M, E_R, E_T, E_H, E_V \in [0 \ldots 1] \]

Weighting of parameters \( W_p \)
Equality function for motifs (1/2)

Comparing 4 parameters of music:
- Melody
- Rhythm
- Tempo
- Harmonisation
- Voice

5 degrees of equality:
\[ E_M, E_R, E_T, E_H, E_V \in [0 \ldots 1] \]

Weighting of parameters \( W_p \)
Equality function for motifs (1/2)

Comparing 4 parameters of music:
- Melody
- Rhythm
- Tempo
- Harmonisation
- Voice

5 degrees of equality:
\[ E_M, E_R, E_T, E_H, E_V \in [0 \ldots 1] \]

Weighting of parameters \( W_p \)
Equality function for motifs (2/2)

Determine $E_P$

Calculate overall degree of equality

$$E = E_V \cdot \sum_p W_p \cdot E_p$$

$p \in \{M, R, T, H\}$

Empirically determined: $E \geq 0.75 \rightarrow \text{similar}$
Comparing entire pieces of music

- For each piece
  - Analyse document
    → List of identified motifs and degree of equality
    \[ D = [(m_1, e_1), (m_2, e_2), \ldots, (m_n, e_n)] \]
  - + Information from lead sheet graph → Abstraction to template

- Comparing pieces ↔ Comparing templates
  - Subgraph isomorphism
  - Graph edit distance
  - Self-defined “distance metric”
Comparing entire pieces of music

For each piece

- Analyse document
  → List of identified motifs and degree of equality
  \[ D = [(m_1, e_1), (m_2, e_2), \ldots, (m_n, e_n)] \]

- Information from lead sheet graph → Abstraction to template

Comparing pieces ↔ Comparing templates

- Subgraph isomorphism
- Graph edit distance
- Self-defined “distance metric”
Comparing entire pieces of music

For each piece
- Analyse document
  → List of identified motifs and degree of equality
  \[D = [(m_1, e_1), (m_2, e_2), \ldots, (m_n, e_n)]\]
- + Information from lead sheet graph → Abstraction to template

Comparing pieces ↔ Comparing templates
- Subgraph isomorphism
- Graph edit distance
- Self-defined “distance metric”
Comparing entire pieces of music

- For each piece
  - Analyse document
    → List of identified motifs and degree of equality
    \[ D = [(m_1, e_1), (m_2, e_2), \ldots, (m_n, e_n)] \]
  - + Information from lead sheet graph → Abstraction to template

- Comparing pieces ↔ Comparing templates
  - Subgraph isomorphism
  - Graph edit distance
  - Self-defined “distance metric”
Self-defined Distance Metric

- Starting point: Two templates $T_1, T_2$

- First step: Determine common sub-template (CST)

- Analyse CST on 4 levels:
  1. Time Level
  2. Structural Level
  3. Semantic Level
  4. Motif Level

- $\rightarrow$ 4 distance values $D_E$,
  Overall distance value:
  \[ D(T_1, T_2) = (D_{\text{Time}}, D_{\text{Struct}}, D_{\text{Semant}}, D_{\text{Motif}}) \]
**Time Level**

- Evaluates length of CST in proportion to length of document (piece)
- \( t_i \) – Length (CST) / Length (piece)
- \( D_{\text{Time}} = \frac{1}{2} \cdot (t_1 + t_2) \)
- States: The **bigger** \( D_{\text{Time}} \), the more similar \( T_1 \) and \( T_2 \)

---

![Diagram](image-url)
Abstraction to lead sheets despite “small modifications”

These modifications are rated (Type $\times$ Relation)

$d_i$ – Modifications in sub-template $i$:

$$D_{\text{Struct}} = \frac{\sum d_i}{|d|}$$

States: The smaller $D_{\text{Struct}}$, the more similar $T_1$ and $T_2$
Semantic Level

What has been found in $T_1$ and $T_2$?

- Different values $\rightarrow$ average

- States: The bigger $D_{\text{Semant}}$, the more similar $T_1$ and $T_2$
Motif Level

- Average degree of equality of all identified motifs
- $e_i$ – equality values

$$D_{Motif} = \frac{\sum e_i}{|e|}$$

- States: The bigger $D_{Motif}$, the more similar $T_1$ and $T_2$
Example from [1]
Test set: 4 different, monophonic pieces of music
- “Auld lang syne” – original
- “Auld lang syne” – motif variations
- Medley: “Auld lang syne” and “Oh, when the saints”
- “Oh, when the saints”

Compared to “Auld lang syne”

Similarity calculated using prototype application

Results illustrated as a 3d chart: *without structural Level*

---

Similarities
Similarities

Dipl.-Inf. Michael Rentzsch
Musical Data Bases
Similarities

Cluster:
Very similar
Similarities

Cluster: Medium similarity

Dipl.-Inf. Michael Rentzsch
Musical Data Bases
Similarities

Time Level

Motif Level

Semantic Level

No similarity
Futher Development

- Build up test repository → MELDEX library
- Improve equality function for motifs (musical aspects ↑)
- Use deduction when searching for motifs
- Apply methods to (symbolic) audio data
- Goal: Indexing documents in a music data base according to musical aspects
Further information about our project Musical Data Bases can be found at

http://www.tu-chemnitz.de/project/mdb