Challenges and opportunities for computational analysis of wax cylinders

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Overview I

Introduction
  Wax cylinders
  Archives

Challenges
  Signal/noise
  Reliability of meta-data
  Recording/playback speed of wax cylinders
  Missing context

Opportunities
  Pitch interval analysis

Conclusion
Wax cylinders

Early field recordings were captured on wax cylinders.

- 1895-1935
- No electricity needed
- Noisy
- Limited frequency range

Figure: A wax cylinder recording from a 1911 expedition by Hutereau.
Archives: ATM (USA), RMCA (Belgium)

Collection of the Royal Museum for Central Africa (RMCA), Tervuren, Belgium
- More than 35,000 items
- Mainly field recordings from Central Africa
- First recordings from 1890s
- Many analogue carriers types
- Challenging meta-data

Archives of Traditional Music at Indiana University (ATM, USA)
Most wax cylinders contain segments with a reasonable signal/noise ratio.

- Segmentation
- Noise levels
- Some repetitive noise sources

Figure: Wax cylinder, a source of noise
Reliability of meta-data — Problems

Meta-data problematic [2, 3]:

- Changing geographical nomenclature
- Many vernacular names for musical instruments
- Transcription of tonal languages (Yoruba, Igbo, Ashanti, Ewe)
- Collection vs scientific field work

Figure: Kombi, Kembe, Ekembe, Ikembe, Dikembe or Likembe?
Reliability of meta-data — Quantify

Check meta-data via duplicate detection[4]
1. Find duplicate items[6]
2. Compare meta-data
3. Analyze differences

2.5% (887 of 35306) duplicates in RMCA archive.

Figure: Comparison of meta-data fields using duplicates
Reliability of meta-data — Fields

<table>
<thead>
<tr>
<th>Field</th>
<th>Empty</th>
<th>Different</th>
<th>Exact match</th>
<th>Fuzzy or exact match</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>20.83%</td>
<td>13.29%</td>
<td>65.88%</td>
<td>65.88%</td>
</tr>
<tr>
<td>People</td>
<td>21.17%</td>
<td>17.34%</td>
<td>61.49%</td>
<td>64.86%</td>
</tr>
<tr>
<td>Country</td>
<td>0.79%</td>
<td>3.15%</td>
<td>96.06%</td>
<td>96.06%</td>
</tr>
<tr>
<td>Province</td>
<td>55.52%</td>
<td>5.63%</td>
<td>38.85%</td>
<td>38.85%</td>
</tr>
<tr>
<td>Place</td>
<td>33.45%</td>
<td>16.67%</td>
<td>49.89%</td>
<td>55.86%</td>
</tr>
<tr>
<td>Language</td>
<td>42.34%</td>
<td>8.45%</td>
<td>49.21%</td>
<td>55.74%</td>
</tr>
<tr>
<td>Title</td>
<td>42.23%</td>
<td>38.40%</td>
<td>19.37%</td>
<td>30.18%</td>
</tr>
<tr>
<td>Collector</td>
<td>10.59%</td>
<td>14.08%</td>
<td>75.34%</td>
<td>86.71%</td>
</tr>
</tbody>
</table>

Table: Comparison of pairs of meta-data fields
<table>
<thead>
<tr>
<th>Original title</th>
<th>Duplicate title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warrior dance</td>
<td>Warriors dance</td>
</tr>
<tr>
<td>Amangbetu Olia</td>
<td>Amangbetu olya</td>
</tr>
<tr>
<td>Coming out of walekele</td>
<td>Walekele coming out</td>
</tr>
<tr>
<td>Nantoo</td>
<td>Yakubu Nantoo</td>
</tr>
<tr>
<td>O ho yi yee yi yee</td>
<td>O ho yi yee yie yee</td>
</tr>
<tr>
<td>Enjoy life</td>
<td>Gently enjoy life</td>
</tr>
<tr>
<td>Eshidi</td>
<td>Eshidi (man’s name)</td>
</tr>
<tr>
<td>Green Sahel</td>
<td>The green Sahel</td>
</tr>
<tr>
<td>Ngolo kele</td>
<td>Ngolokole</td>
</tr>
</tbody>
</table>

Table: Pairs of fuzzily matched titles. The fuzzy match algorithm is based on Srensen/Dice coefficients.
Recording/playback speed of wax cylinders

Recording speed often unknown.

- Various systems (G)
- 80-240 cycles/s
- Some use reference tones

Absolute pitch unreliable.

Figure: Wax cylinder, speed unknown
Context needed for a deep understanding of single recordings. A few aspects:

- Dance
- Language
- Religion
- Instrument building

Audio only offers a limited snapshot of (music) culture. Context might be changed dramatically and impossible to re-create.

Figure: Wax cylinder, without context
Opportunities

Unique snapshots of century old musical practices. Opportunities for comparative studies:

- Compare current with past practices
- Compare musical idioms with western idioms
- Universals in scales?
Opportunities

Pitfall
- Noisy
- Unreliable meta-data
- Recording speed unknown
- Context missing for individuals

Avoidance
- Select less noisy segments manually
- Limit meta-data dependency
- Avoid claims about absolute pitch
- Focus on patterns, systems, populations
Pitch interval analysis

Manual, computer assisted analysis with Tarsos [5]

Figure: Tarsos software system for pitch analysis.
Pitch interval analysis - 4 PC
Pitch interval analysis - 5 PC

<table>
<thead>
<tr>
<th>Interval size (cents)</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0000</td>
<td>0</td>
</tr>
<tr>
<td>0.0005</td>
<td>0.0010</td>
</tr>
<tr>
<td>0.0010</td>
<td>0.0015</td>
</tr>
<tr>
<td>0.0015</td>
<td>0.0020</td>
</tr>
</tbody>
</table>

Figure: Four pitch classes

\[ \frac{16}{22} \]
Pitch interval analysis - 6 PC

![Histogram of pitch intervals with density values.](image)
Pitch interval analysis - 7 PC
Pitch interval analysis - Preliminary results

Very large diversity but some general findings:

- The fifth is almost always present.
- Scales with four and five PC’s share 240 cents as basic interval.
- Scales with six and seven pitch classes share 170 cents

Figure: Diversity in 55 pentatonic scales, ordered by interval size of first interval.
Conclusion

- Presented a way to quantify meta-data quality in digital music archives via duplicates[4, 1]
- Presented challenges and opportunities to research on wax cylinder recordings
- Preliminary results on pitch content of 400 wax cylinders


Panako - A scalable acoustic fingerprinting system handling time-scale and pitch modification.