Frequency Domain Detection Algorithm for Electric Guitar String Bending

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Motivation

• Bending is like singing, requires precision and articulation, signifies personal style.

• Every guitarist bends in his own way... some can’t even bend! A robust detection is necessary.

• Bending example: Steve Vai - With liberty and justice for all!
Problem Definition

• To analyze the characteristics of string bending: waveform and pitch [2, 3, 4]

• Compare similar guitar playing techniques for disambiguity

• Develop an algorithm to detect string bending onsets

Software Tools

- MATLAB: algorithm scripts
- GarageBand: recording and editing
- Praat: waveform and pitch analysis
  http://www.fon.hum.uva.nl/praat/
ADSR Curve & Pitch Analysis
Bending vs Picking

- Aside from discrete pitch variation, picking might even cause time-domain waveform to be separated tool, since touching string with pick stops string vibration (this can be used to play *staccato*).
- In spectrogram the part looks noisy.
String Bending vs Sliding

- Both in time domain: no picking “attack”, sharp increase in magnitude
- Frequency domain: bending - *continuous pitch variation*; sliding - *step function*, no gap like picking
Comparison to Vibrato

- Semitone bending vs. vibrato
- Difference in pitch variation range: use a threshold to distinguish

The pitch contour for vibrato is like a sine wave, so tracking the curve with long enough memory helps identifying vibrato. For example, if we take derivatives, there would be several local maximum and minimum points.
Fundamental Frequency to MIDI Pitch Number

- MIDI pitch class number, preserving micro-tonality
  \[ p = 69 + 12 \times \log_2 \left( \frac{f}{440 \text{ Hz}} \right) \]
- 69 is A440

An octave higher: frequency doubled pitch number increase by 12
Algorithm Block Diagram

Input audio → Fundamental frequency → Pitch (Hz) → MIDI pitch class number

A440 = 69.00 (100 cents)

Detection algorithm → Arrange into column vectors → Eliminate “undefined” Pitch sample
“Sandwich” Concept

• Must go through middle point: falls within a range with $p + 0.5$ as center, set this range with a threshold $t$

• Decision rule: adjacent samples falls within this range
Experiment Setup

- From self-recorded YouTube videos ([link!!!!])
- Parameters: decision threshold $t$ (for boundary of decision range), sample spacing in Praat

<table>
<thead>
<tr>
<th>Threshold (MIDI pitch)</th>
<th>[0 0.2 0.4 0.6 0.8 0.1 0.2 0.3 0.4 0.5]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample spacing (seconds)</td>
<td>Automatically decided by Praat</td>
</tr>
</tbody>
</table>

Tuesday, May 10, 2011
Test Data

- Self-recorded YouTube video excerpts
- *Listen to and guess* how many bends are there for each test excerpt??
- C major pentatonic lick - all sliding
- C blues progression - bending, low SNR
- Blues with hybrid picking - bending
- Never Give Up! - pull off, tapping, sweep picking
**C Major Pentatonic**

<table>
<thead>
<tr>
<th>( t )</th>
<th>0.4</th>
<th>0.3</th>
<th>0.2</th>
<th>0.1</th>
<th>0.08</th>
<th>0.06</th>
<th>0.04</th>
<th>0.02</th>
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</thead>
<tbody>
<tr>
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<td>46</td>
<td>28</td>
<td>24</td>
<td>21</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

- Correct answer should be: 0, so there are totally 14 errors.
- *Never Give Up!* also has no string bending, but the test result is correct for it.
- What causes the difference?
Tablature

- **Legato** slide, hammer on and pull off, no bending
- Probably because samples are closer in time and pitches are close too!
- For *Never Give Up!*, there is always either a spacing of octaves or triads
Threshold vs Detection

- For *Blues with hybrid picking*
- Red line being ground truth
- Optimal parameter is the intersection
- Boundary point where $t = 0.5$ is unimportant
- Other curves can be found online
Decision Rule Flaws

- Easy to calculate but the linear assumption is somewhat impractical, some sample might “escape”
- Need better curve fitting and decision rules
- $t$ too big: include vibrato as bending (false alarm)
- $t$ too small: if bending produces non-linear pitch transition curve, then adjacent samples might fall out of decision range, as figure on right. The decision rule will think those samples are vibrato then omit this bending
Future Work

• Multimodal: using visual cue [1, 2]

• Real-time: short delay for windowing since the computation of the algorithm is simple, $O(N)$ with $N$ being the window length

• Distinguish different types of bending: up, down, pre, picking mixed, tapping with bending, ... and many other tricks!

• Polyphonic string bending detection: instrument (different guitars treated as different instruments) separation

• Beat tracking to lower computational complexity (less samples)

• Is it reasonable and how to HMMs for this research? Incorporate melody tracking for microtones
Questions...?
Reference


