

Pitch Detection: Music, Physics, and the Brain

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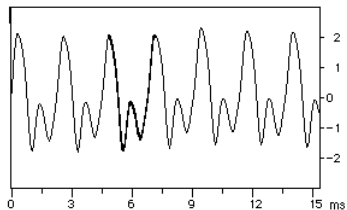
Contents

- Aim of Pitch Detection
- Historical Background
- A Little Music Theory
- Physics of Sound
- Proposed Real-Time Algorithm
- Future Considerations
- Biological Inspiration for the Future
- Fin.

Aim

Take in an acoustic musical signal, and output the notes present.

Aim



A4

A Little History

history

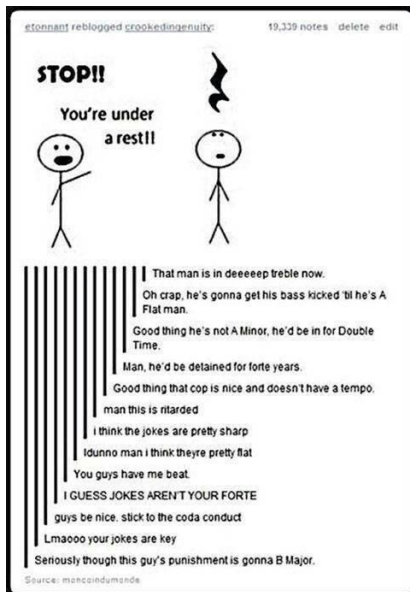
Pythagoras & Early Music (c. 550BC)



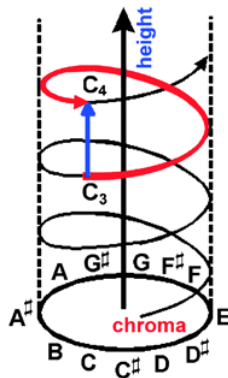
Helmholtz & the Rise of Psychoacoustics (1800s)



Some Basic Music Theory



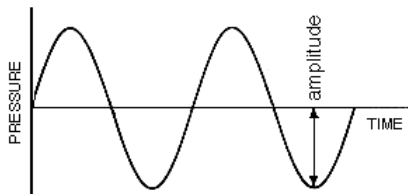
Categorising Notes



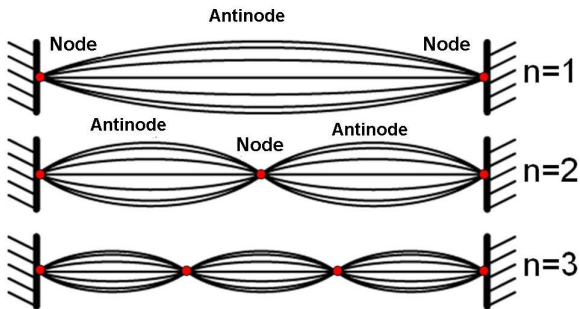
Categorising Notes



Musical Notes



Standing Waves



Harmonics

Diagram illustrating the intervals between the first 16 harmonics (partials) of a string, labeled 1 through 16, arranged on a two-staff musical system (treble and bass clefs).

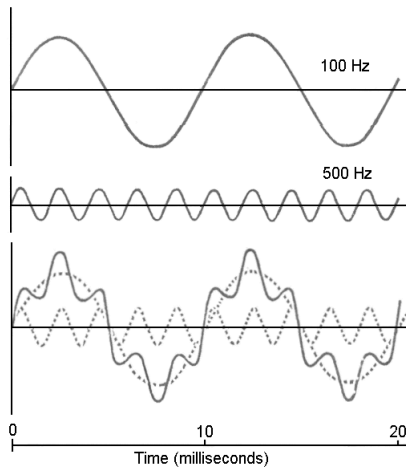
Intervals (Top Staff):

- 1 to 2: octave ↓
- 2 to 3: perfect fourth ↓
- 3 to 4: minor third ↓
- 4 to 5: supermajor second ↓
- 5 to 6: "lesser tone" ↓
- 6 to 7: lesser undecimal neutral second ↓
- 7 to 8: lesser tridecimal 2/3-tone ↓
- 8 to 9: just diatonic semitone ↓

Intervals (Bottom Staff):

- 1 to 2: perfect ↑ fifth
- 2 to 3: major ↑ third
- 3 to 4: subminor ↑ third
- 4 to 5: "greater ↑ tone"
- 5 to 6: greater ↑ undecimal neutral second
- 6 to 7: greater ↑ tridecimal 2/3-tone
- 7 to 8: septimal ↑ diatonic semitone

Implications



Timbre



Tuning fork



Flute



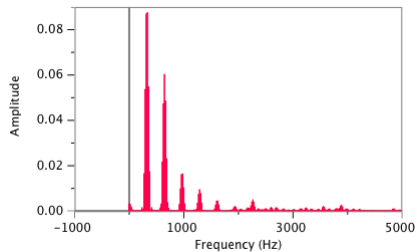
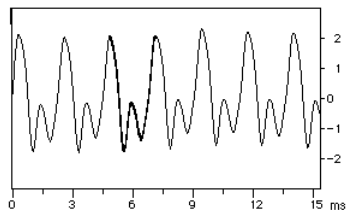
Voice



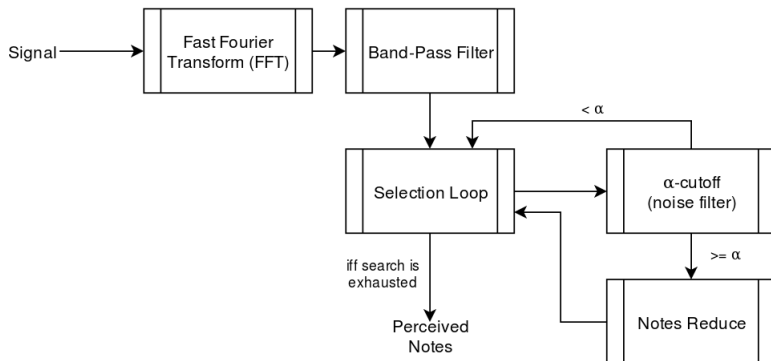
Violin



The Fourier Transform



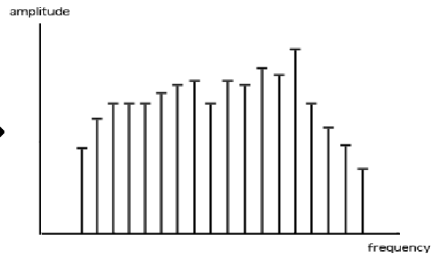
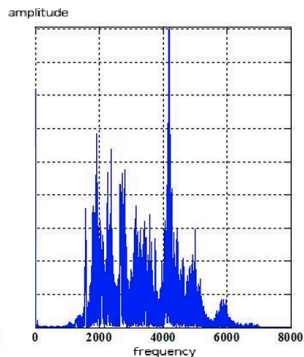
Overview



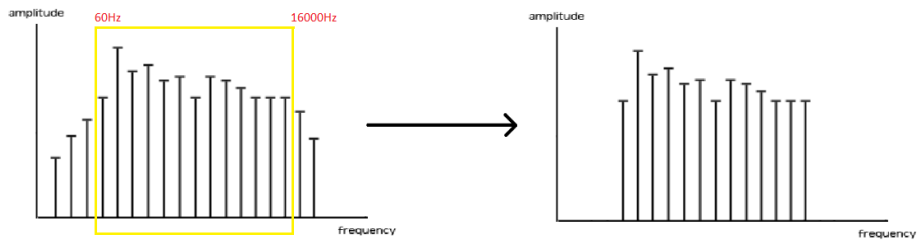
Assumption - No Undertones



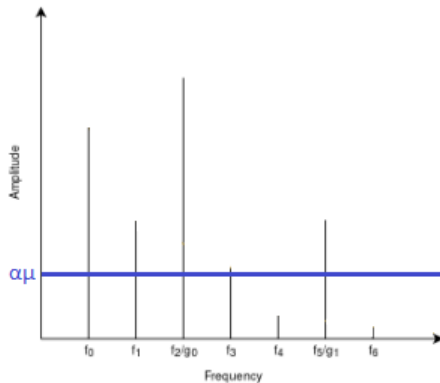
Clustering



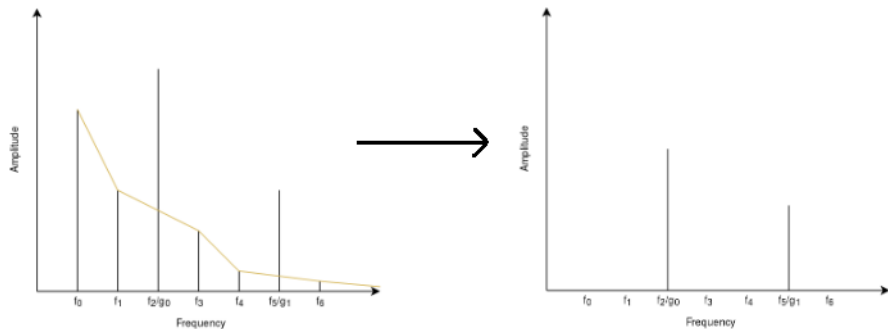
“Band-Pass” Filter



Selection Loop & α -cutoff



Notes Reduce



Testing

The image displays four systems of musical notation, likely for a piano or similar instrument, used for testing a real-time algorithm.

- System 1:** Two staves in treble clef, key of D major (two sharps), common time (C). The first staff contains a sequence of eighth and quarter notes. The second staff contains a similar sequence of eighth and quarter notes.
- System 2:** A grand staff (treble and bass clefs) in key of D major, common time. The tempo/mood marking is "Lento con gran espressione". The first measure is marked with a first ending bracket (1) and a piano (*p*) dynamic. The second measure is marked with a piano-piano (*pp*) dynamic. The notation includes chords, single notes, and rests. Below the bass staff, there are rhythmic markings: "meo. * meo. * meo. * meo. * meo. * meo. *".
- System 3:** Two staves in treble clef, key of D major, common time. Both staves feature a sequence of chords (dyads or triads) played in a rhythmic pattern.
- System 4:** Two staves in treble clef, key of D major, common time. Both staves feature a sequence of chords (dyads or triads) played in a rhythmic pattern, similar to System 3.

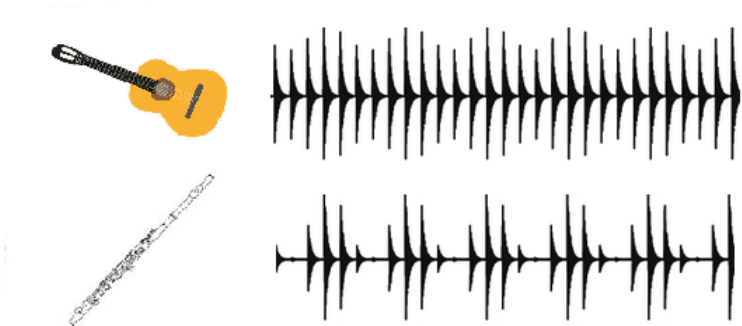
Results

	Precision	Recall	Specificity	Accuracy	F-Score
Test 1	78.09%	93.89%	83.00%	86.89%	84.78%
Test 2	100.00%	97.22%	100.00%	97.85%	98.55%
Test 3	82.46%	75.67%	77.52%	76.36%	78.85%
Test 4	86.31%	82.50%	53.33%	75.83%	83.47%
Test 5	65.08%	100.00%	64.29%	79.07%	78.47%
μ	82.39%	89.86%	75.63%	83.20%	84.82%

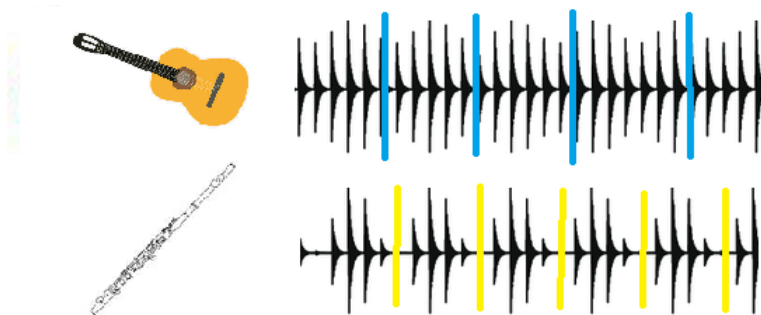
Further Considerations

- Adapt evaluation to use a larger & more widely-adopted dataset (eg. MAPS)
- Adapt 'Notes Reduce' to model harmonics on an instrument-to-instrument basis
- Apply source separation to reduce polyphonic problems to multiple monophonic problems
- Take temporal aspects of sound into account
- Take inspiration from biological systems for pitch detection in humans (such as the ear/brain)

A Human Solution



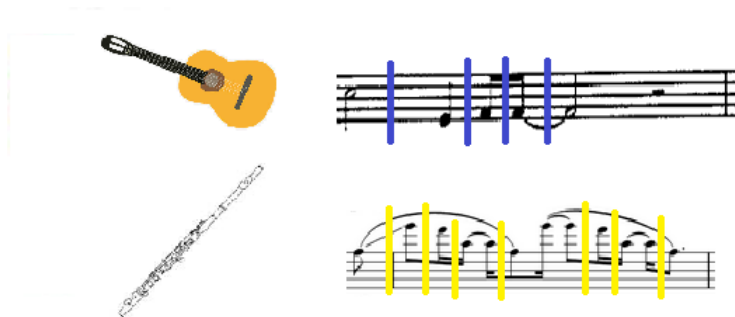
A Human Solution



A Human Solution



A Human Solution



A Human Solution



A Human Solution



A Human Solution



A Human Solution



A Human Solution



A Human Solution



Some Thoughts for the Future

- Do the ear and brain process monophonic and polyphonic signals in different ways?
- How does the brain subconsciously abstract timbre?
- Can we build models and solutions in similar ways?

Questions?

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Slides at <http://tomg.io/research-skills-slides.pdf>

Paper at <http://tomg.io/isspit-1.pdf>

Feel free to ask any questions!