AUTOMATIC MIXING

Dissonance suppression during harmonic mixing

A journey through the DJ world

by Stefan Hamburger

July 2017

Seminar Topics in Computer Music

Prof. Paolo Bientinesi, RWTH Aachen

WHAT IS AUTOMATIC MIXING?

Generating a continuous stream of music with smooth transitions

Track A → Track B

DJS IN A CLUB

HISTORY OF DJING

Francis Grasso: beatmatching

Technics SL-1200 (1971)

HISTORY OF DJING

1986: Harmonic Keys magazine (Stuart Soroka)

TOP 40

BPM	TITLE / ARTIST	KEY
120	Hot for You - Viola Wills	G minor
122	Someone Like You - Sylvester	G minor
124	They're Playing Our Song - Trinere	D minor
122	Knock Me Senseless - E. Bound Xway	D minor
122	Movin' On - Robby Hood/Muchmore	D minor
118	Certain Things Are Likely - KTP	E minor in A major out
116	When I Think of You - Janet Jackson	A major
119	Take Me As I Am - Erotic & Exotic	E major
102	(+ 0.5%) Mutual Attraction - Sylvester	D minor
103	C'est La Vie - Robbie Nevil	D minor
102	Nipple to the Bottle - Grace Jones	A minor
101	Don't Stop the Feeling - Yarbrough & Peoples	D minor
117	Concentration Break Down - George Black	D minor
118	Come As You Are (Remix) - Peter Wolf	G minor
117	Mr. Right - Ealanore Mills	C minor
117	Feels Like The First Time - Sinitta	C minor
117	One Look - Paul Parker (B side Man Parrish Version)	C minor

HISTORY OF DJING

Camelot Sound (Mark Davis)

EasyMix wheel

HISTORY OF DJING

- 1999: first DJ software
- 2006: harmonic mixing software

Mixxx software

WHAT IS HARMONY?

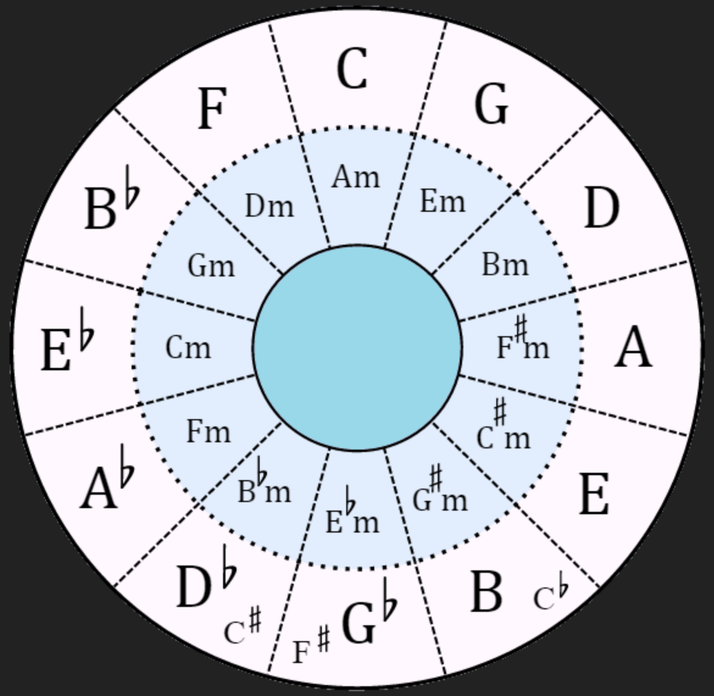
Universal to all humans,

but varies based on personal experience

MUSIC THEORY

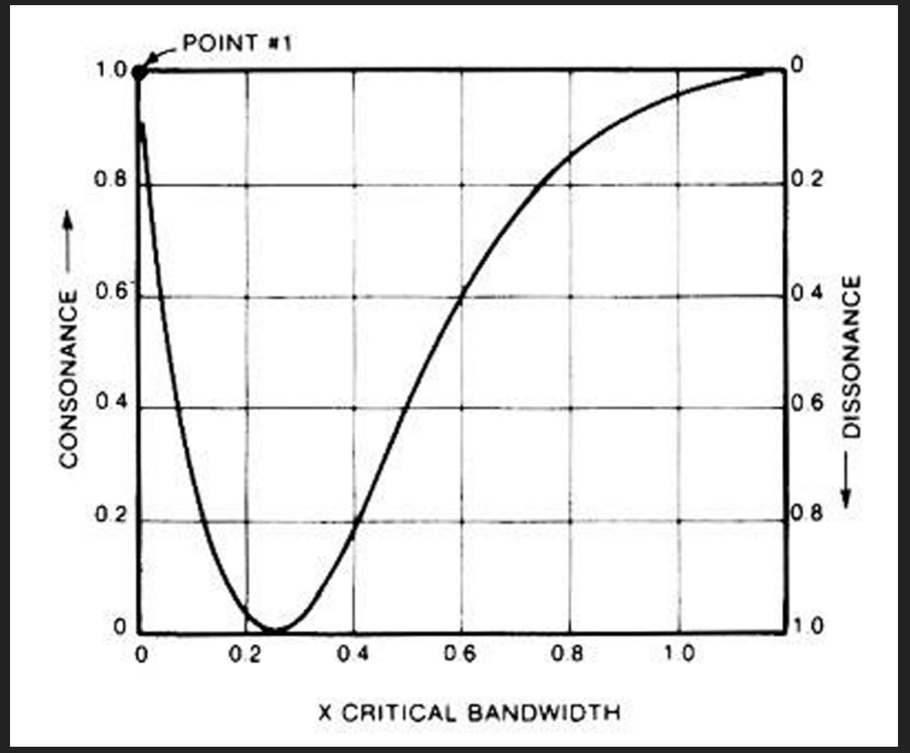
Consonant intervals:
octave, perfect fifth, major third

Dissonant intervals:
semitone, tritone



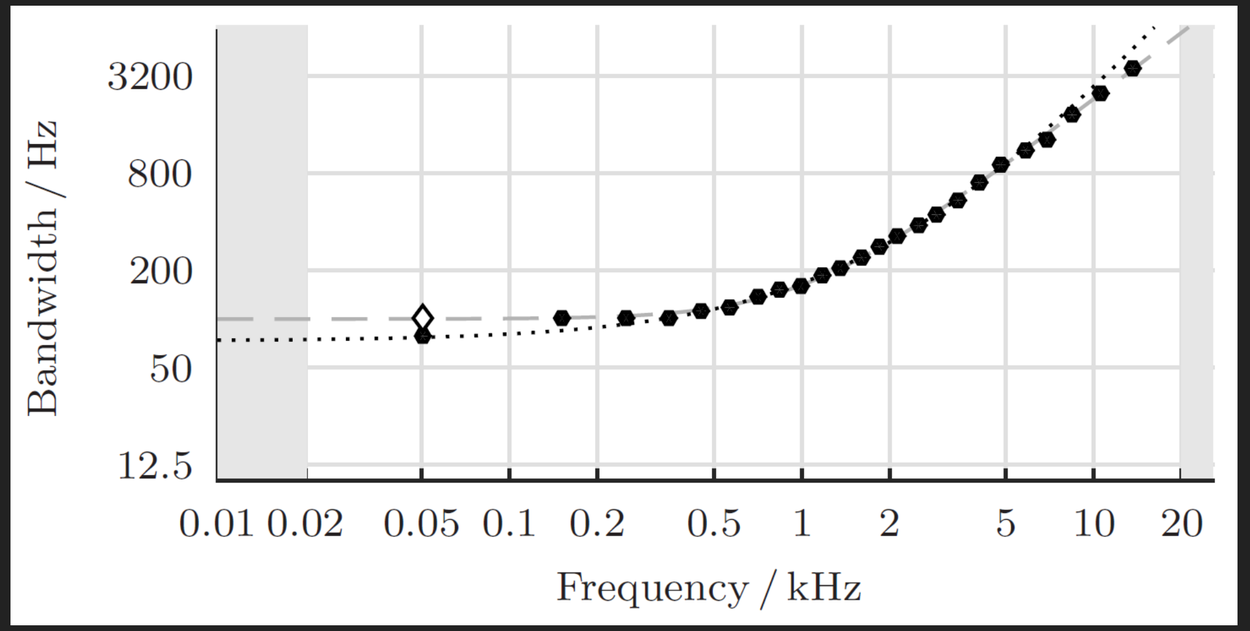
Circle of Fifths *(Quintenzirkel)*

PSYCHOACOUSTICS



Roughness

CRITICAL BANDWIDTH



$$CBW(f) = 25 + 75 \cdot (1 + 1.4 \cdot (\frac{f}{1000})^2)^{0.69}$$

Zwicker (1961), Zwicker and Terhardt (1980)

ROUGHNESS

Given: f_1, f_2

$$y = \frac{|f_2 - f_1|}{CBW(\frac{f_1+f_2}{2})}$$

$$Roughness(f_1, f_2) = max(\underbrace{(e^1 \cdot \frac{y}{0.25} \cdot e^{-\frac{y}{0.25}})^2}_{=16y^2 \cdot e^{2-8y}}, 0) \in [0, 1]$$

HARMONIC SERIES

(NATURTONREIHE)

Fundamental frequency f

$$f, 2f, 3f, 4f, 5f, \ldots$$

OCTAVE EQUIVALENCE

$$\ldots \hat{=} A_4 \hat{=} A_5 \hat{=} A_6 \hat{=} \ldots$$

$$\ldots \hat{=} 440Hz \hat{=} 880Hz \hat{=} 1760Hz \hat{=} \ldots$$

TONES AND SEMITONES

$$f + 2f + 3f + 4f + 5f + \dots$$

$$f + \dots + 1.25f + \dots + 1.5f + \dots + 1.75f + \dots + 2f$$

12 semitones: A, A#, B, C, C#, D, D#, E, F, F#, G, G#

TUNING

Equal temperament (12-TET)

$$f_i = 440\ Hz \cdot 2^{\frac{i}{12}}, i \in \mathbb{Z}$$

Tone	A_4	$A\sharp_4$	B_4	C_4	$C\sharp_4$	D_4	$D\sharp_4$	E_4	F_4	$F\sharp_4$	G_4	$G\sharp_4$	A_5
Hertz	440	466.16	493.88	523.25	554.37	587.33	622.25	659.26	698.46	739.99	783.99	830.61	880
	= 440				≈ 550			≈ 660					= 880

9.5

ROUGHNESS

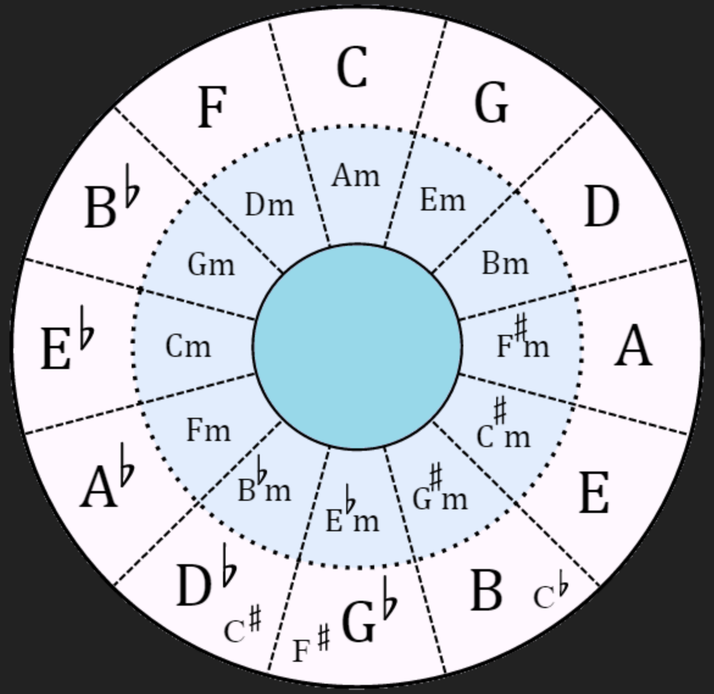
Given two complex tones

$$T_1 = \{(a_1, f_1), (a_2, f_2), (a_3, f_3), \ldots\},$$
$$T_2 = \{(a_4, f_4), (a_5, f_5), (a_6, f_6), \ldots\}$$

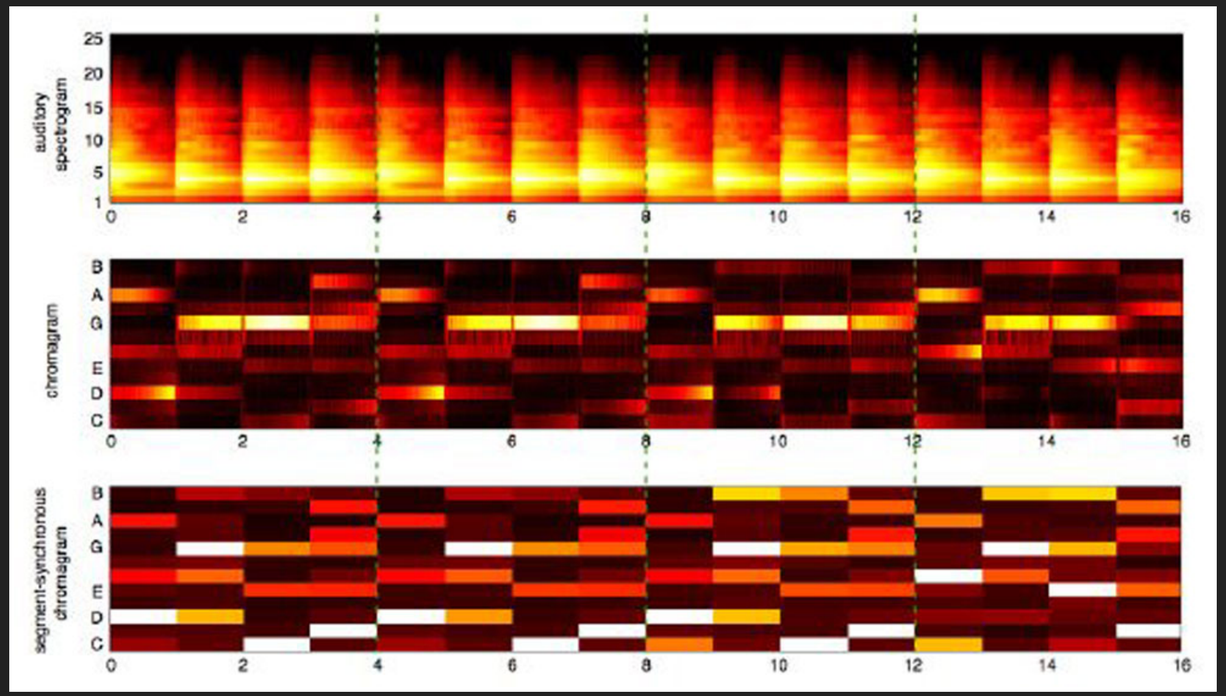
$$Roughness(T_1, T_2) = \frac{\sum_{(a_i,f_i)\in T_1} \sum_{(a_j,f_j)\in T_2} a_i \cdot a_j \cdot Roughness(f_i, f_j)}{\sum_{(a_i,f_i)\in T_1} \sum_{(a_j,f_j)\in T_2} a_i \cdot a_j} \in [0, 1]$$

PREVIOUS APPROACHES

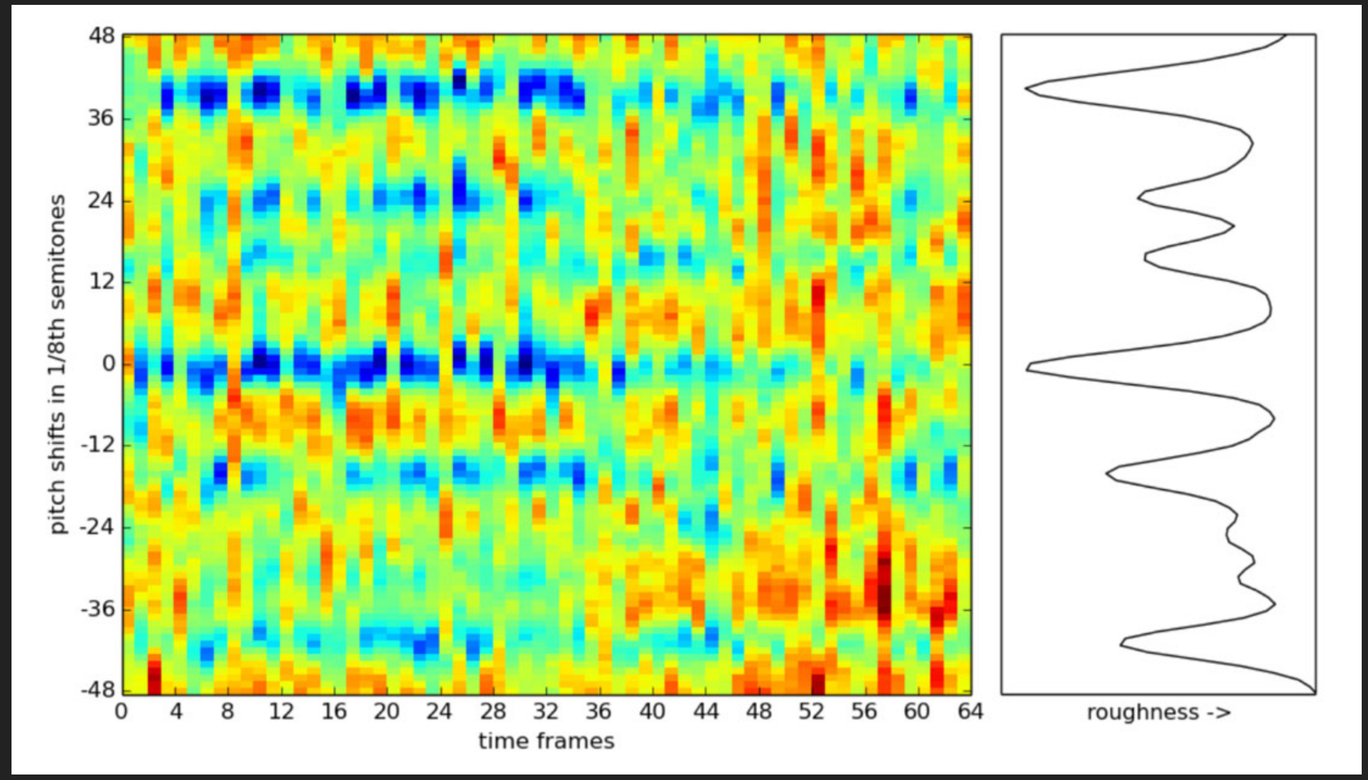
KEY ESTIMATION



CHROMA BASED

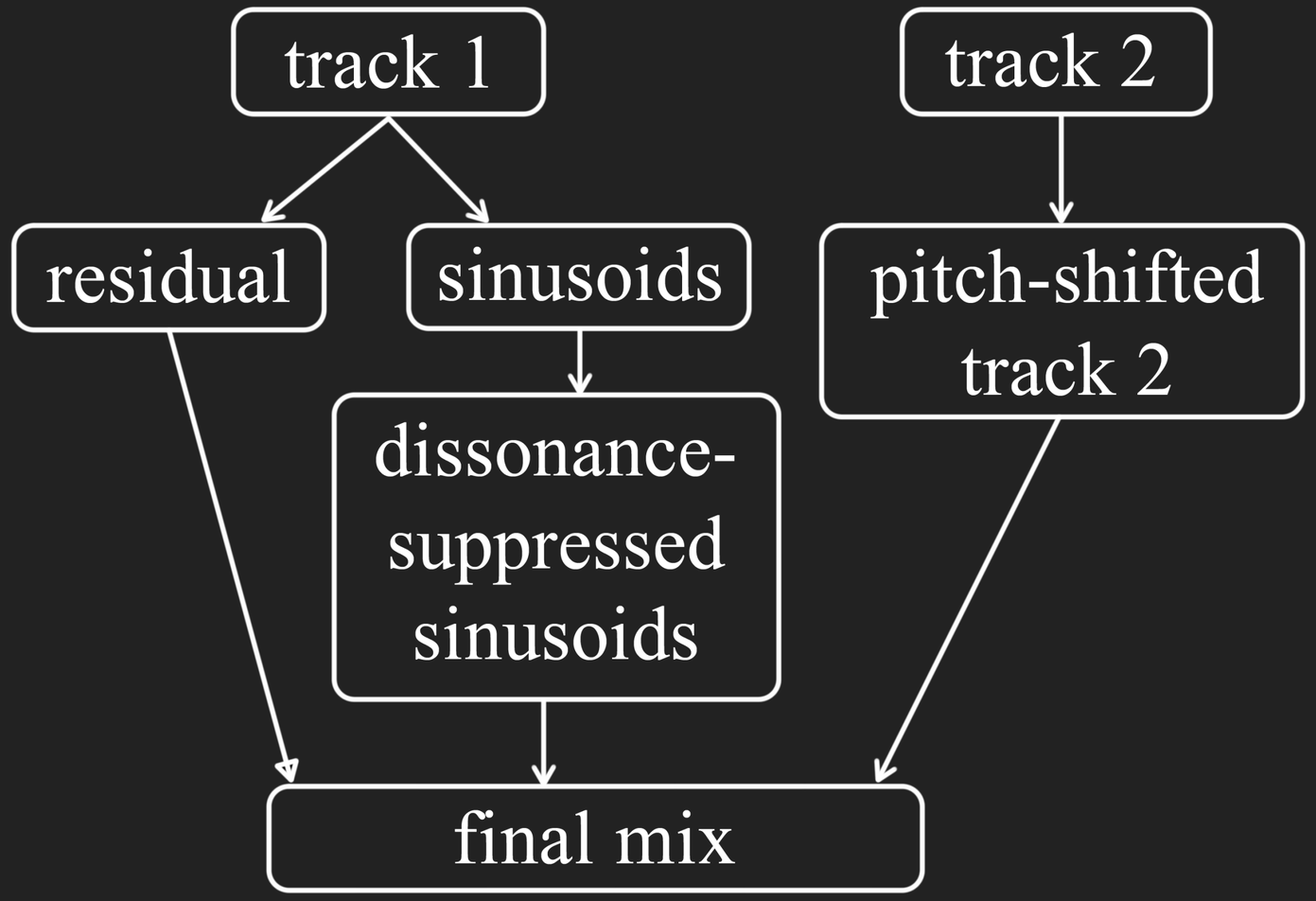


ROUGHNESS BASED



“TECHNIQUES FOR AUTOMATIC DISSONANCE SUPPRESSION IN HARMONIC MIXING”

Master thesis by Vittorio Maffei (2014-2015)


track 1
track 2
residual
sinusoids
pitch-shifted track 2
dissonance-suppressed sinusoids
final mix

PREPROCESSING

Tracks converted to mono, 44,100 Hz

Tempo changed to 120 bpm

8 second samples = 16 beats

SHORT TIME FOURIER TRANSFORM (STFT)

Blackman window

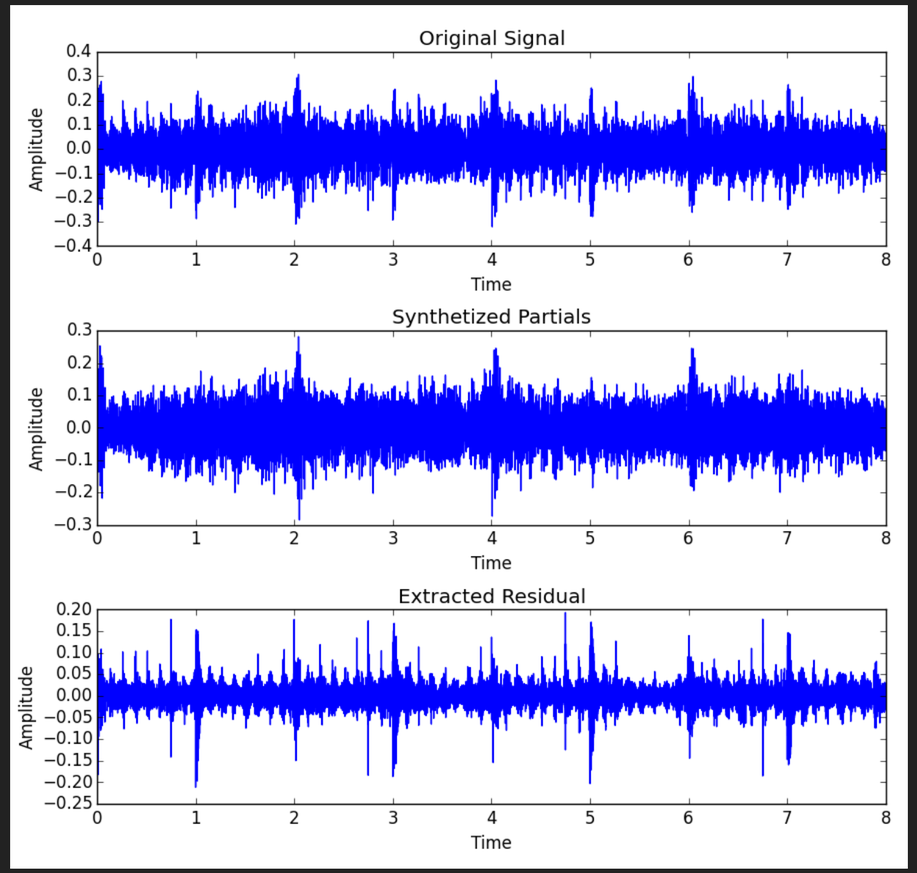
4096 window size, 256 hop size

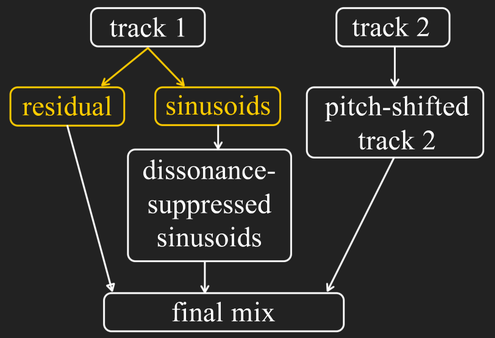
4096 bins, 5000 Hz max frequency

→ 20 strongest partials extracted

RESIDUAL EXTRACTION

Split signal into sinusoids and residuals

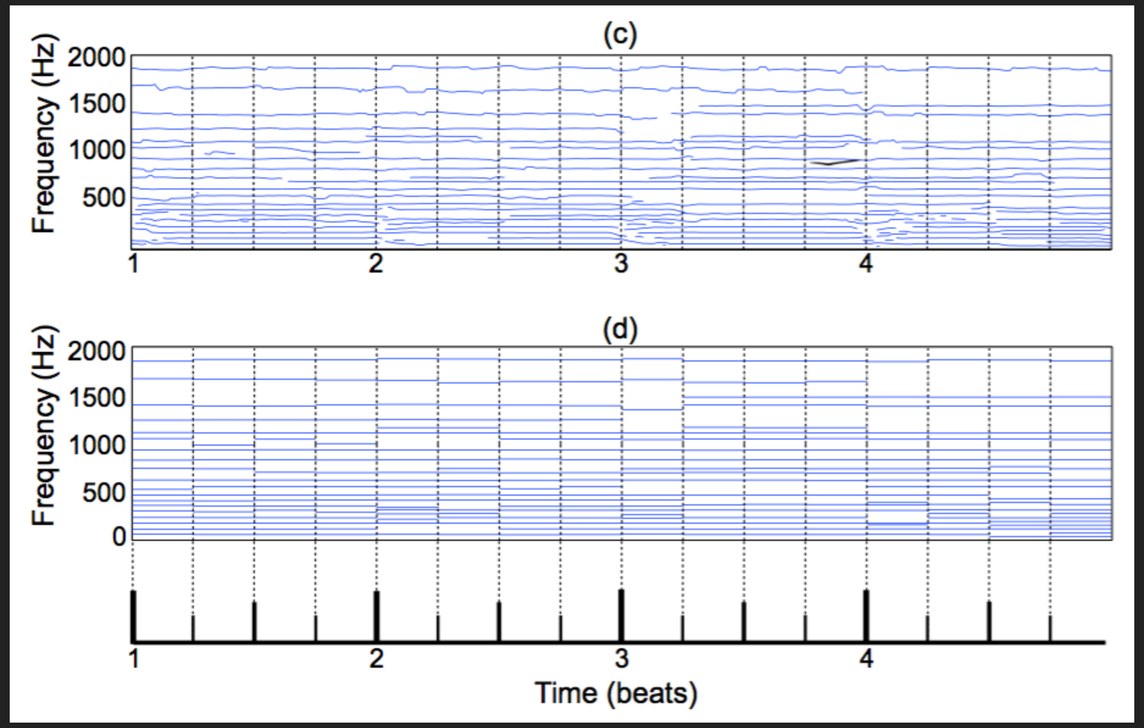




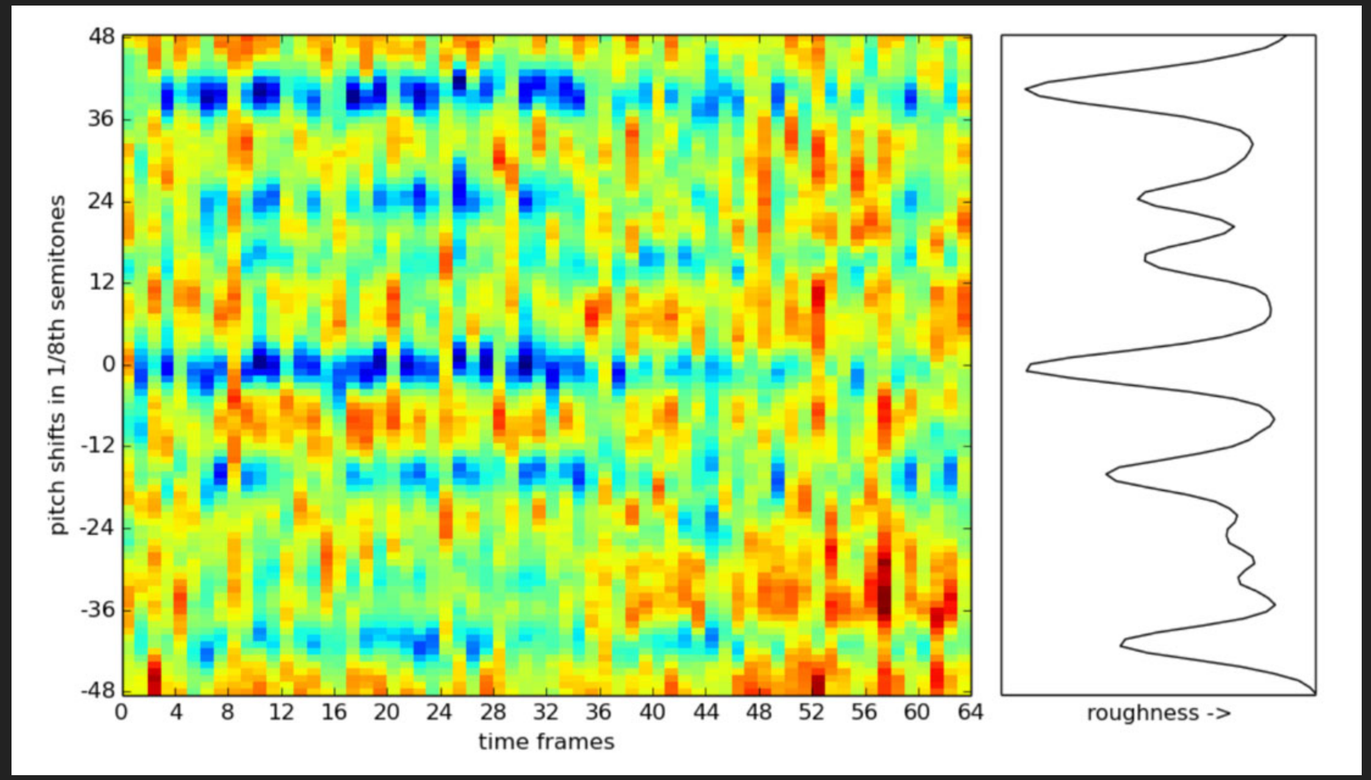
TEMPORAL AVERAGING

Averaged to 16th notes

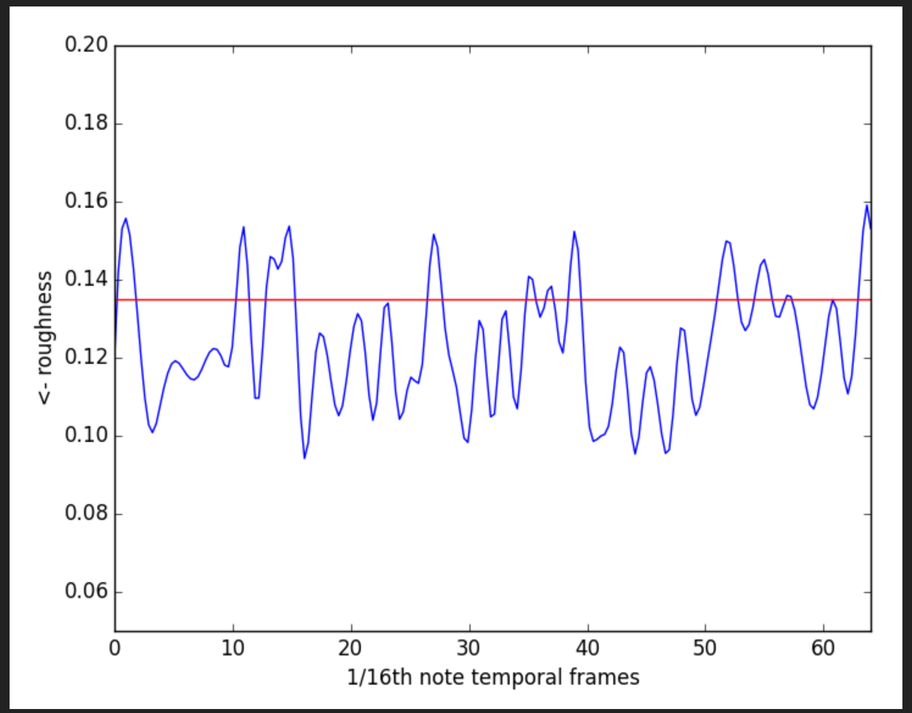
1379 windows → 64 windows

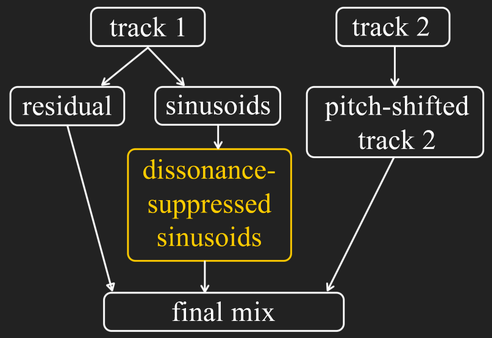


OPTIMAL PITCH-SHIFT

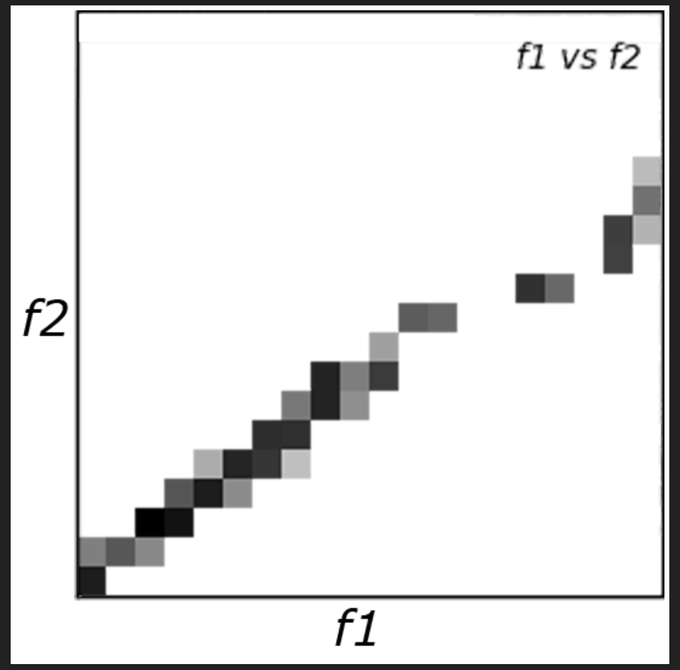


DISSONANCE SUPPRESSION





PARTIALS SUPPRESSION



RESULTS

- Improvements to disharmonic mixes
- No changes to already harmonic mixes

CRITICISM

- Only tested on 8 second fragments
- Only tested by musically trained listeners
- No audio samples provided
- Used existing libraries, did not build a new tool
- Many typos

FUTURE WORK?

- Machine learning
- Volume/loudness adjustment

OBLIGATORY SOURCES

- *Papers*
  - Vittorio Maffei: Techniques for automatic dissonance suppression in harmonic mixing. Master thesis at University of Milan, 2015.
  - Richard Parncutt: Harmony: A Psychoacoustical Approach. Springer 1989.
  - Florian Völk: Updated analytical expressions for critical bandwidth and critical-band rate. DAGA 2015, Nuremberg.
  - Dave Cliff: Hang the DJ: Automatic Sequencing and Seamless Mixing of Dance-Music Tracks. HP Laboratories Bristol, 2000.
  - Harmonic Keys magazine. 1986-1987.
- *Videos*
  - Howard Goodall: How Music Works. 4-part TV series on Channel 4 (UK), 2006.
  - William Cox: Timeseries Data Superpowers: Intuitive Understanding of FIR Filtering and Fourier Transforms. OSCON 2014.
  - Meinard Müller, Peter Grosche: Tempo and Beat Tracking. AudioLabs Erlangen, 2016.
  - Tony Prince: The History of DJ. Video series by DMC.
  - CD Projekt Red: The Witcher 3 : Wild Hunt. Music: General Approach. Wwise Tour 2016, Warsaw.
  - PCDJ: various press videos from 2000
  - Leonard Bernstein: The Unanswered Question. Lecture series at Harvard, 1973.
- *Websites*
  - Camelot Sound, company website.
  - Web Audio API, MDN Web Docs.
- *For a complete list of sources, see the slide notes.*

TAKEAWAYS

- Roughness measure
  (¼ of CBW = most dissonant)
- Harmonic series
  $(f, 2f, 3f, \ldots)$

5 minutes of harmonic mixing (demo for Mixed in Key):