Mazurka Project

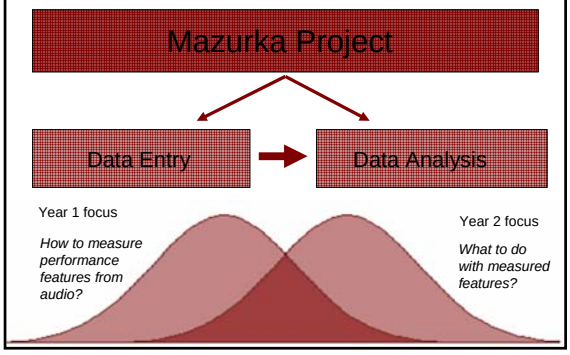
29 June 2006
CHARM Symposium

Craig Stuart Sapp

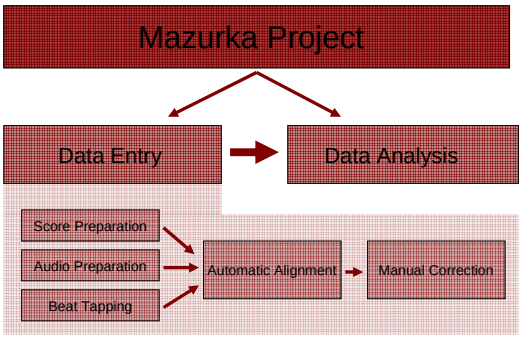
Sections

1. Overview
2. Power Measurements
3. Manual Correction
4. Automatic Alignment
5. Experiments
6. Performance Simulations
7. Initial Analysis

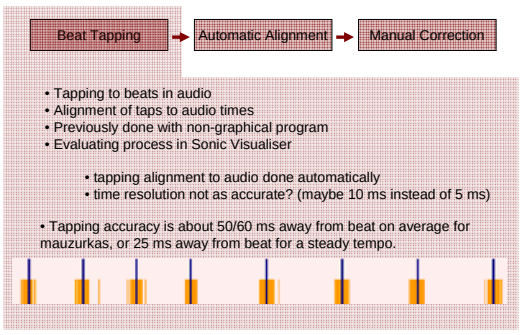
Top-Down Overview



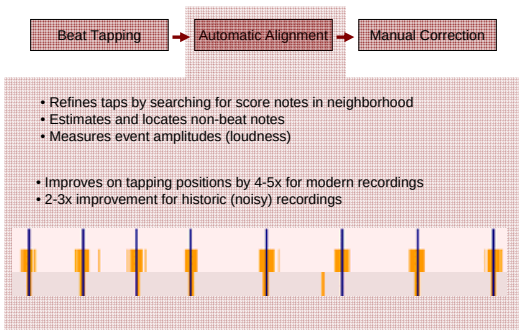
Top-Down Overview



Data Entry Process



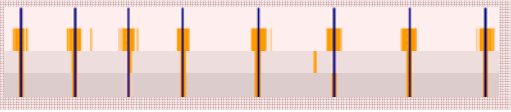
Data Entry Process



Data Entry Process

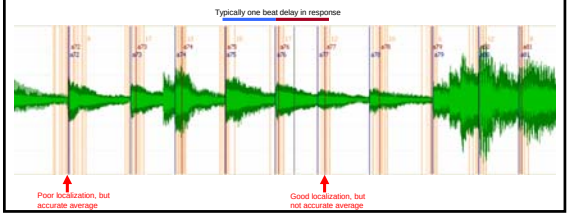
Beat Tapping → Automatic Alignment → Manual Correction

- Fix obvious errors in automatic alignment
- Verify automatic alignment by listening to clicks and music simultaneously



Reverse Conducting

- Orange = individual taps (multiple sessions) which create bands of time about 100 ms wide.
- Red = average time of individual taps for a particular beat
- Blue = actual beat onset times



Power Measurements (for manual corrections)

MzPowerCurve

- *Sonic Visualiser plugin to do various power measurements*

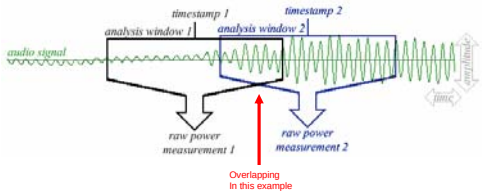
  http://sv.mazurka.org.uk/MzPowerCurve

- #1 raw power measurements – average and weighted

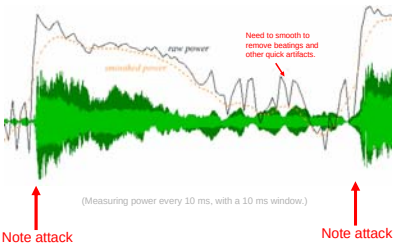
$$P_{avg} = 10\log_{10}\left(\frac{1}{N}\sum_n x_n^2\right) \qquad P_{wavg} = 10\log_{10}\left(\frac{1}{N}\sum_n x_n^2 w_n\right)$$

- #2 smoothed power – useful for basic dynamics measurements
- #3,4 smoothed power slope – useful for manual corrections of note attacks (for percussive instruments such as piano).

Window and Hop



Raw and Smoothed power



- Smoothed power useful for getting basic dynamics levels.

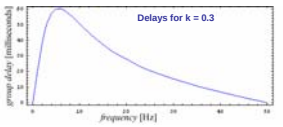
Smoothing Filter

• Using a filter called an *exponential smoother*:

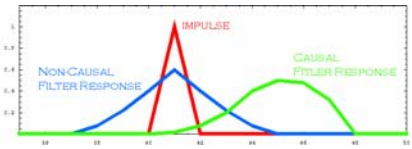
$$y[n] = k\ x[n] + (1-k)\ y[n-1]$$

Englishish: The current output equals the current input times the value *k*, plus the previous output times the value 1-*k*.

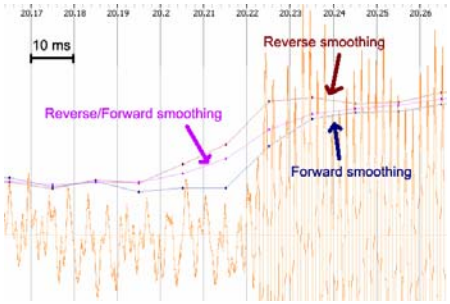
• All filters delay the input. Since this filter feeds back on itself, the filter will delay some frequencies more than others:



Symmetric Filtering



Filtering Direction



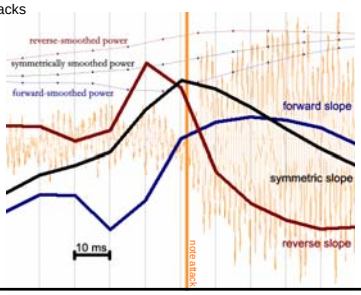
Smoothing Direction

• Avoid the funny delays by symmetric filtering

• Then slope of smoothed power aligns nicely with percussive note attacks

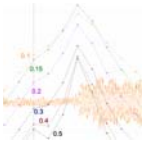
• symmetric filtering is best for localizing attacks

• reverse filtering is best for dynamics estimation

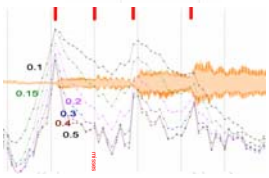


Smoothed Power Slope

Attack on measurements

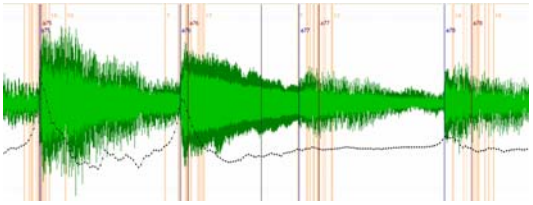


Attack ½ between measurements



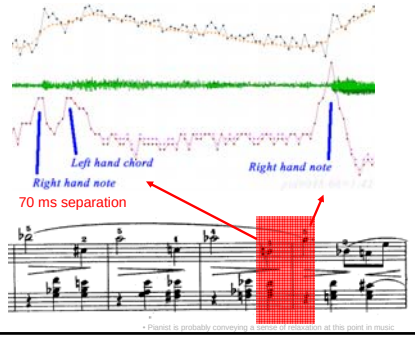
• smoothing factor of about 0.2 gives best results over a variety of conditions

Power Slope for Correcting



Not helpful for this beat (no peak)

Non-Synchronous Hands



• > 30 ms separation may be significant

Advantages/Disadvantages

• Time domain analysis, so localization can be better than for frequency analysis metrics (E.g. Earis & Bello methods)

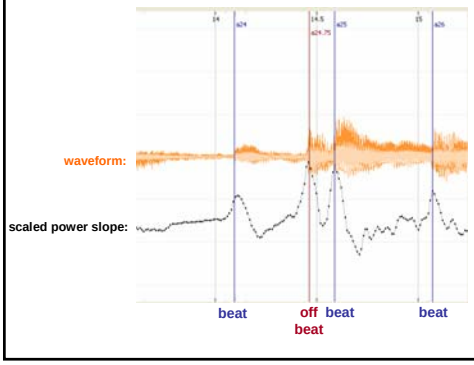
• Ignores frequency content, so not always or accurate.

•Good for instruments with percussive attacks (i.e. piano, drums)

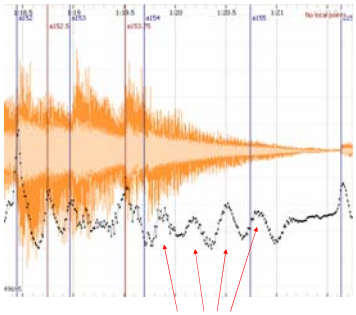
• Probably not good for non-percussive instruments: voice, violin, woodwinds, brass, etc.

Manual Correction

Beats + Offbeats

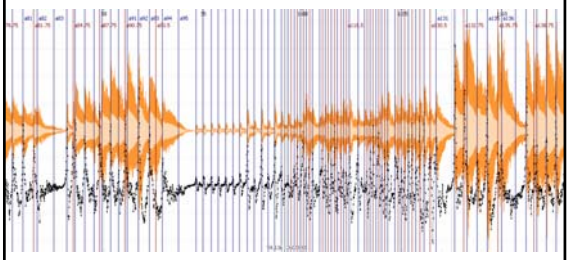


Advantage of Having the Score



• If you don't have a score, you are wasting your time.

Large-scale View of Beats/Offbeats



• Layer clicks can be played with different timbres/loudness.

Probable Entry Scenario

0. Become familiar with the performance. (Score already entered) (15 min)
- Tap to performance in Sonic Visualiser (5 min)
- Cursory check of beat positions with onset annotations (10 min)
- Interpolate off-beat positions based on score
- View/listen to audio with beats/off-beats and automatic annotations (10 min)
- Automatic adjustments of the onset times of beats/off-beats
- Careful manual proof listening/reading of the automatically adjusted times (30 min)
- Extract secondary performance features such as dynamics and non-simultaneous chord notes.

red: manual time estimates for a 5 minute piece

→ about 2 hours for 5 minutes of music

Automatic Alignment Evaluation

Summary

• Automatic alignment improves accuracy about 4-5x for modern recordings and 2-3x for historic recordings when compared to reverse conducting accuracy.

• **Earis system parameter search optimization**

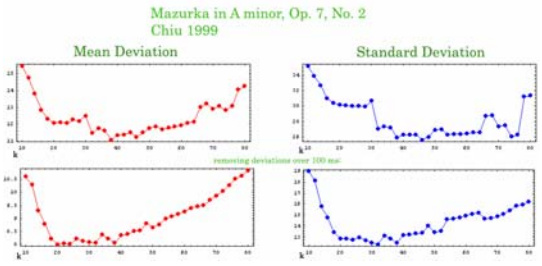
1. wavenumber (k)
2. low-pass filter order (LPF)
3. tuning factor

• **Other evaluation/exploration for the system:**

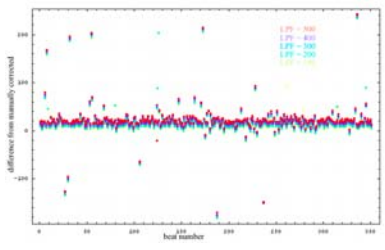
1. search window method
2. square/Gaussian window method
3. recursive processing
4. wanderer identification
5. removing harmonics of previous event
6. symmetric LPF filtering

k Parameter Sensitivity

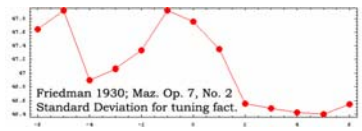
k = wave number (how many cycles of a sinewave) to analyze with

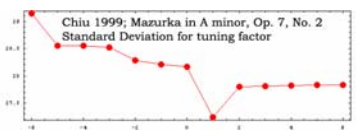


LPF Parameter

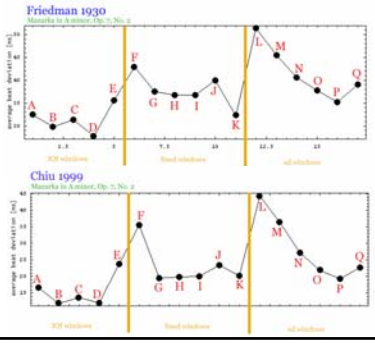


Tuning parameter





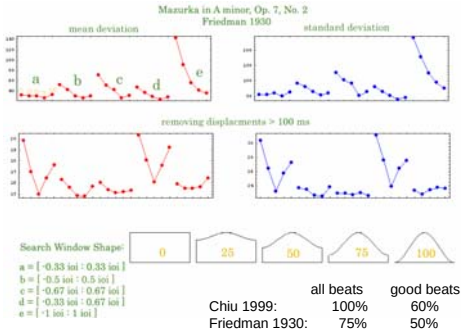
Windowing Methods



a = [-0.33 ioi : 0.33 ioi]
b = [-0.50 ioi : 0.50 ioi]
c = [-0.67 ioi : 0.67 ioi]
d = [-0.33 ioi : 0.67 ioi]
e = [-1.00 ioi : 0.67 ioi]
f = [-100 ms : 100 ms]
g = [-200 ms : 200 ms]
h = [-300 ms : 300 ms]
i = [-400 ms : 400 ms]
j = [-500 ms : 500 ms]
k = [-200 ms : 500 ms]
l = [-1 sd : 1 sd]
m = [-2 sd : 2 sd]
n = [-3 sd : 3 sd]
o = [-4 sd : 4 sd]
p = [-5 sd : 5 sd]
q = [-2 sd : 4 sd]

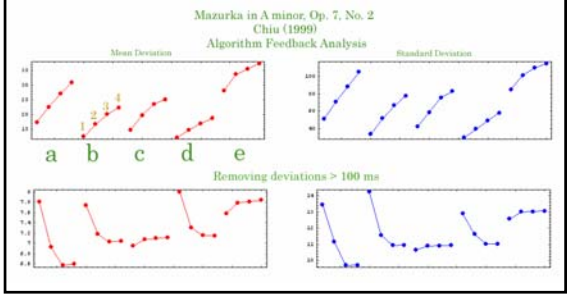
• IOI is best method

Hybrid Window Shape



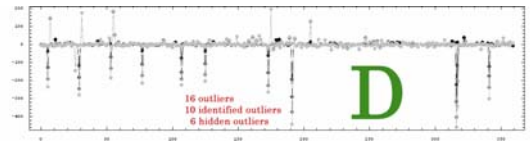
	all beats	good beats
Chiu 1999:	100%	60%
Friedman 1930:	75%	50%

Recursion effect on localization

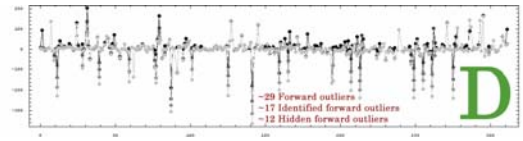


Recursion & Wandering

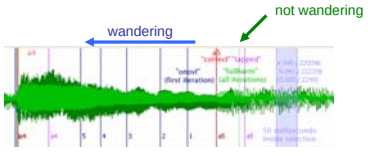
modern recording



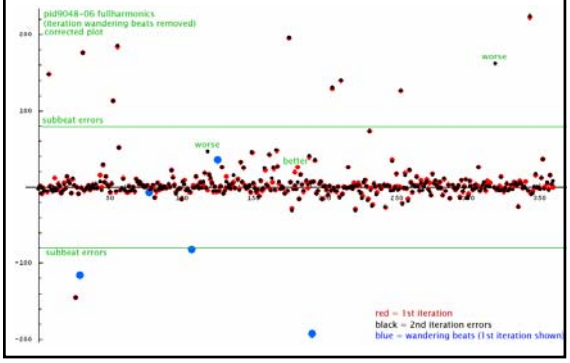
historic recording



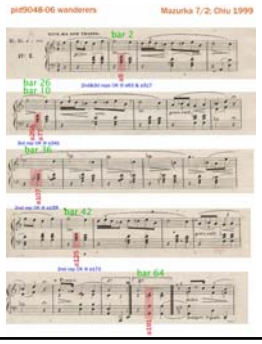
Wandering



Wanderers

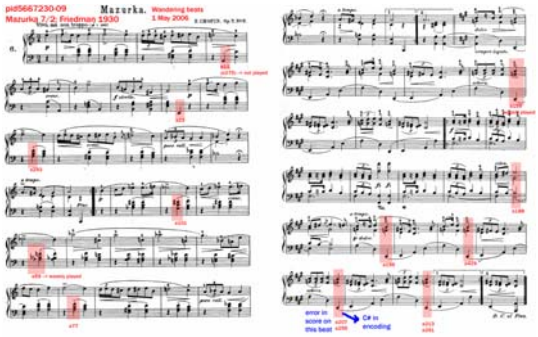


Wanderers (2)



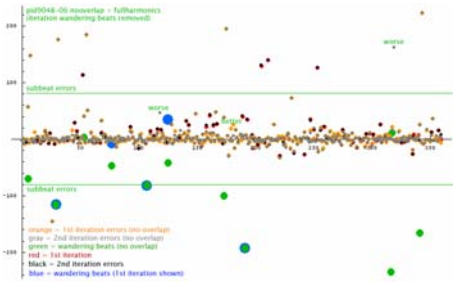
• events which the analysis method cannot "see".

Wandering (3)



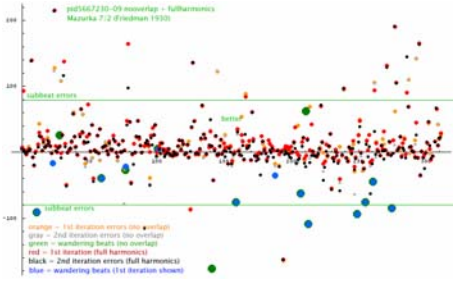
Selective Harmonics

• Remove shared harmonics with previous event to improve attack identification and remove potentially beating harmonics.



• Removing shared harmonics with previous events didn't help: more wanderers.

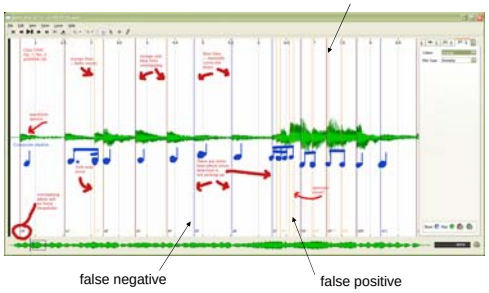
Selective Harmonics (2)



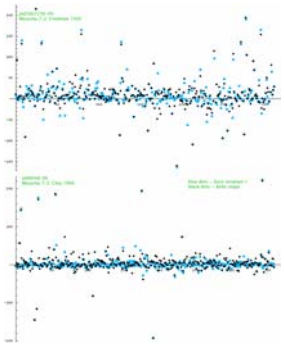
Bello Onsets

http://mazurka.org.uk/auto/onset

• Spectral measurements used to identify event onset locations
• Can give false positivies and false negatives
• Does not utilize a score



Onset Snapping

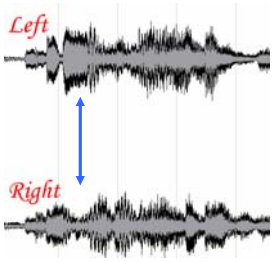


• Snap earis to bello if a bello onset is less than 50 ms away.

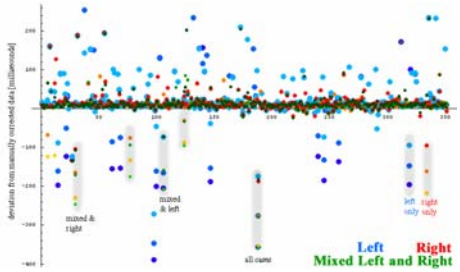
Friedman 1930, Mazurka 7/2:
iteration 1 mean deviation: 22.0 ms
bello snapping md: 22.1 ms

Chiu 1999, Mazurka 7/2:
iteration 1 mean deviation: 10.5 ms
bello snapping md: 13.4 ms

Stereo Differences

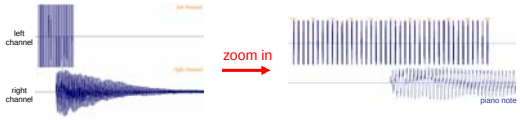


Stereo Comparison

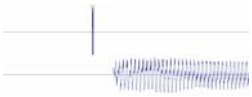


Experiments

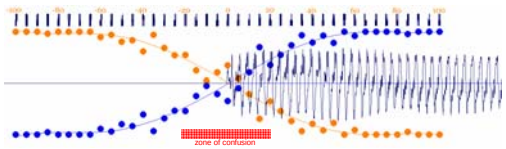
Note Onset Time Resolution



• Play one of these clicks and ask listener: did it come before or after the start of the piano note?



Note Onset Time Resolution

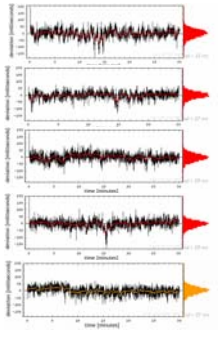


• 75% accuracy or better outside -21.2 to +22.0 ms range around note attack.

• Symmetric about the note onset.

• Very accurate to distinguish which came first when difference is > 60 ms.

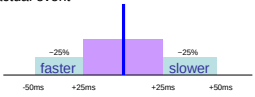
Tapping Accuracy



• Tap for 30 minutes to a constant tempo

• 50% of taps occur within +/- 25 ms of actual event

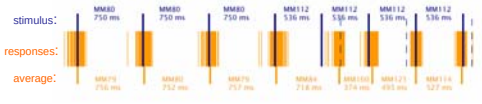
• 95% of taps occur within +/- 50 ms of actual event



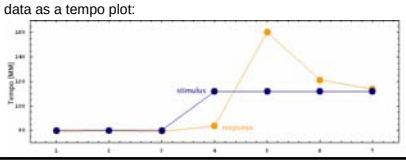
• For Mazurkas (significant tempo changes), accuracy is about twice as much (50% occur within 50 ms of actual event).

Unpredictable Tempo Changes

- **Tapping to an unknown sudden change in tempo**
- Suddenly faster:

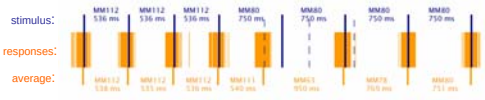


Same data as a tempo plot:

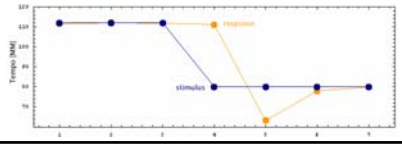


Unpredictable Tempo Changes (2)

- **Tapping to an unknown sudden change in tempo**
- Suddenly slower:

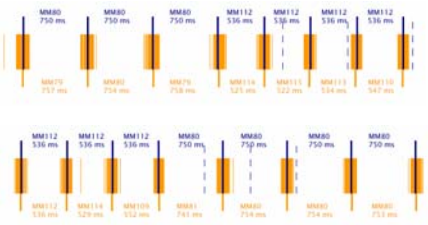


Same data as a tempo plot:

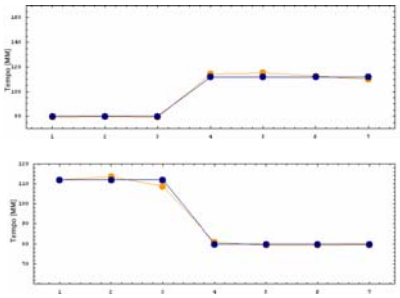


Predictable Tempo Changes

- Tapping to an **known** sudden change in tempo:



Predictable Tempo Changes



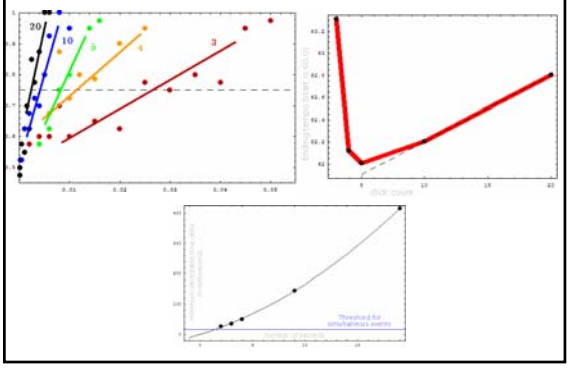
Tempo JND

- How little can the tempo change before it is noticed?

clicks:	3	4	5	10	20
JND:	0.0265	0.0115	0.0082	0.0040	0.0024
faster end delta:	-26.5	-34.4	-48.9	-142.7	-404.9
slower end delta:	26.5	34.6	49.5	145.3	416.0
faster end tempo:	63.3	62.1	62.0	62.2	62.8
slower end tempo:	56.9	57.0	58.0	57.9	57.3

3:	60.0	63.3								
4:	60.0	61.05	62.1							
5:	60.0	60.67	61.33	62.0						
10:	60.0	60.28	60.55	60.83	61.10	61.38	61.65	61.93	62.2	

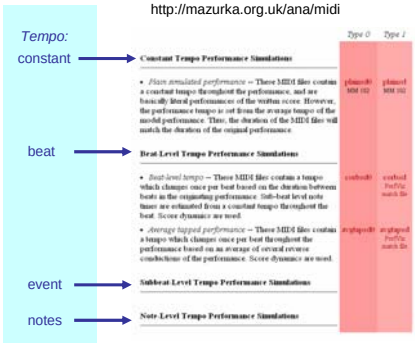
Tempo JND (2)



Performance Simulations

Performance Feature Layers

http://mazurka.org.uk/ana/midi



Performance Components

Tempo/Timing

1. Average tempo (of entire piece)
2. Beat-to-beat tempo
3. Sub-beat timings (continuous tempo)
4. Non-simultaneous events (LH/RH, arpgggios)

Dynamics

1. Score dynamics
2. Composite loudness
3. LH/RH loudness
4. Individual note loudness

PerfViz

• 3D performance worm visualiser by Martin Gasser (Vienna)

MIDI file **+** **Match file**

```
info(matchFileVersion,2.0).
info(scoreFileName,'STDIN').
info(midiFileName,'pid9048-06-corbsdpv.mid').
info(midiClockUnits,480).
info(midiClockRate,500000).
info(keySignature,[an,minor]).
info(timeSignature,3/4).
info(approximateTempo,102.4).
snote(n1,[e,n],5,0:3,0,1,0,1,[])-note(1,[e,n],5,1656,2428,2428,43).
snote(n2,[f,n],5,1:1,0,3/16,1,1:75,[])-note(2,[f,n],5,2428,2925,2925,49).
snote(n3,[e,n],5,1:1,3/16,1/16,1.75,2,[])-note(3,[e,n],5,2925,3090,3090,41).
snote(n4,[a,n],3,1:2:0,1,2,3,[])-note(4,[a,n],3,3090,3366,3366,40).
snote(n5,[d,n],4,1:2:0,1,2,3,[])-note(5,[d,n],4,3090,3366,3366,40).
snote(n6,[f,n],4,1:2:0,1,2,3,[])-note(6,[f,n],4,3090,3366,3366,40).
snote(n7,[d,n],5,1:2:0,1,2,3,[])-note(7,[d,n],5,3090,3642,3642,40).
snote(n8,[a,n],3,1:3:0,1,3,4,[])-note(8,[a,n],3,3642,3912,3912,43).
snote(n9,[d,n],4,1:3:0,1,3,4,[])-note(9,[d,n],4,3642,3912,3912,43).
snote(n10,[f,n],4,1:3:0,1,3,4,[])-note(10,[f,n],4,3642,3912,3912,43).
snote(n11,[f,n],5,1:3:0,1,3,4,[])-note(11,[f,n],5,3642,4181,4181,39).
snote(n12,[f,n],5,2:1,0,2,4,6,[])-note(12,[f,n],5,4181,5301,5301,62).
snote(n13,[a,n],3,2:2,0,1,5,6,[])-note(13,[a,n],3,4649,4975,4975,39).
snote(n14,[c,n],4,2:2,0,1,5,6,[])-note(14,[c,n],4,4649,4975,4975,39).
```

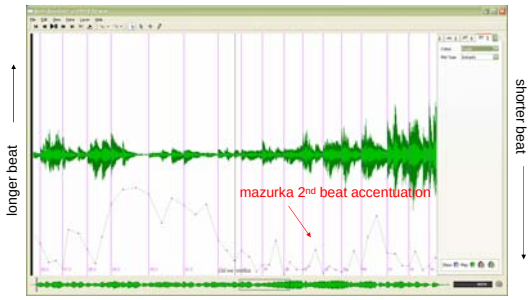
PerfViz (2)

3 Axes:

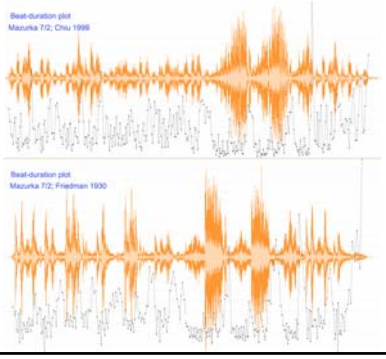
1. Time
2. Tempo
3. Loudness

Initial Analysis

Beat Durations

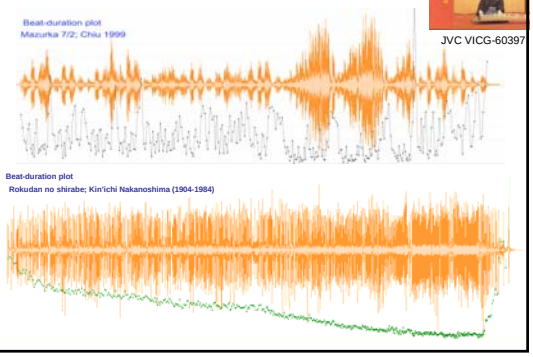


Beat Durations (2)

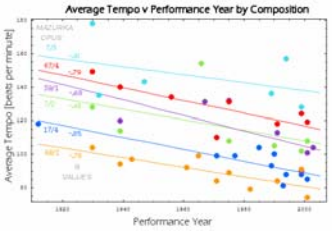


Tempo and Style

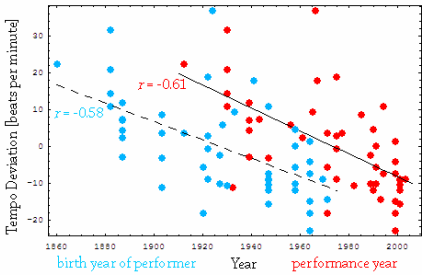
JVC VICG-60397



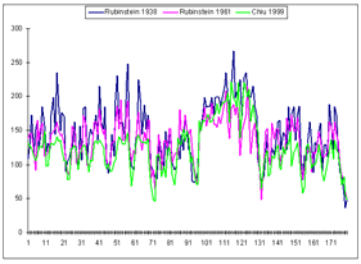
Average tempo over time



Average tempo over time (2)



Mazurka in F Major, Op. 68, No. 3

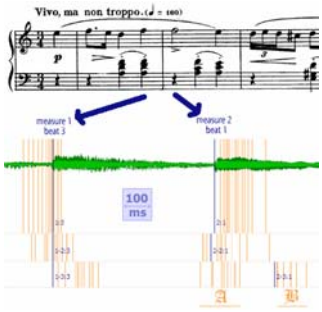


Rubinstein 1938
MM134

Rubinstein 1961
MM129

Chiu 1999
MM115

Repeats



Dynamics