DECODING THE SENSUALITY IN MUSIC

Elaine Chew
Professor of Digital Media
Queen Mary University of London
School of Electronic Engineering and Computer Science
Centre for Digital Music

Why care about music experience

- Explosion in digital music information
- Rise of music information research/retrieval

IFPI Global Music Report: Key figures

- **Global recorded music revenue: US$15.7b** (2016)
- Global revenue growth: 5.9%
- **Digital share of global revenues: 50%**
- **Digital revenue growth: 17.7%**
- **Growth in streaming revenues: 60.4%**
- Physical revenues: -7.6%
- Download revenues: -20.5%

2017

International Federation of the Phonographic Industry

Industry-scale digital music applications

- Last.fm (www.last.fm)
- Pandora (www.pandora.com)
- Shazam (www.shazam.com)
  - 120M monthly active users (2016)
  - 30B song identification requests, +20M per day
- Spotify (www.spotify.com)
  - 60M subscribers, >140M active users

Why care about music experience

- Explosion in digital music information
- Rise of music information research/retrieval
- Understand how humans process music
- Appreciate how humans experience music

Agenda

- A moving experience
  - Strong emotions: frisson, laughter, awe
- Expectation
  - Fulfillment: Reward
  - Violation: Surprise, laughter
- Tension, anticipation
  - Delayed resolution
  - Density of activity

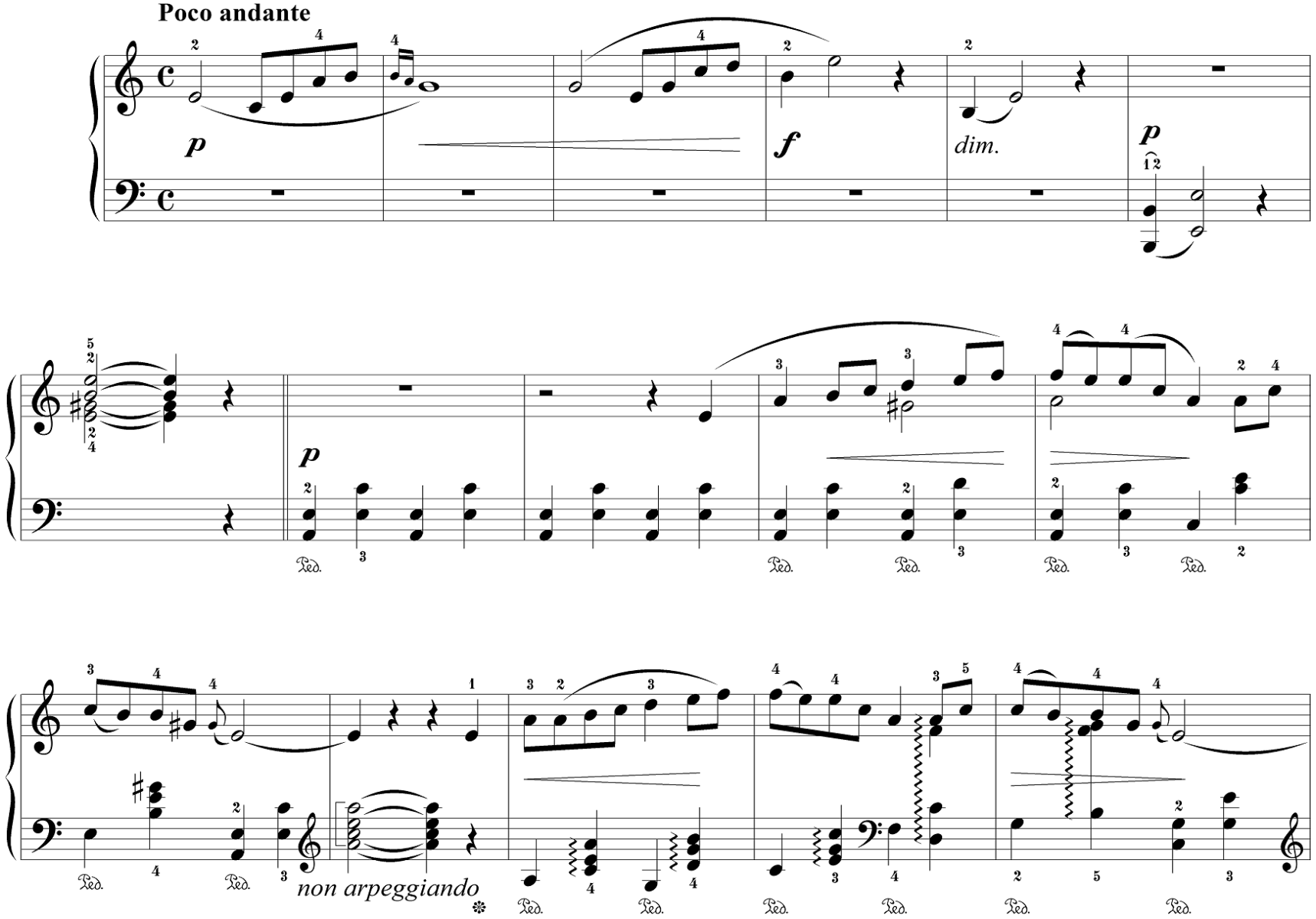
Agenda

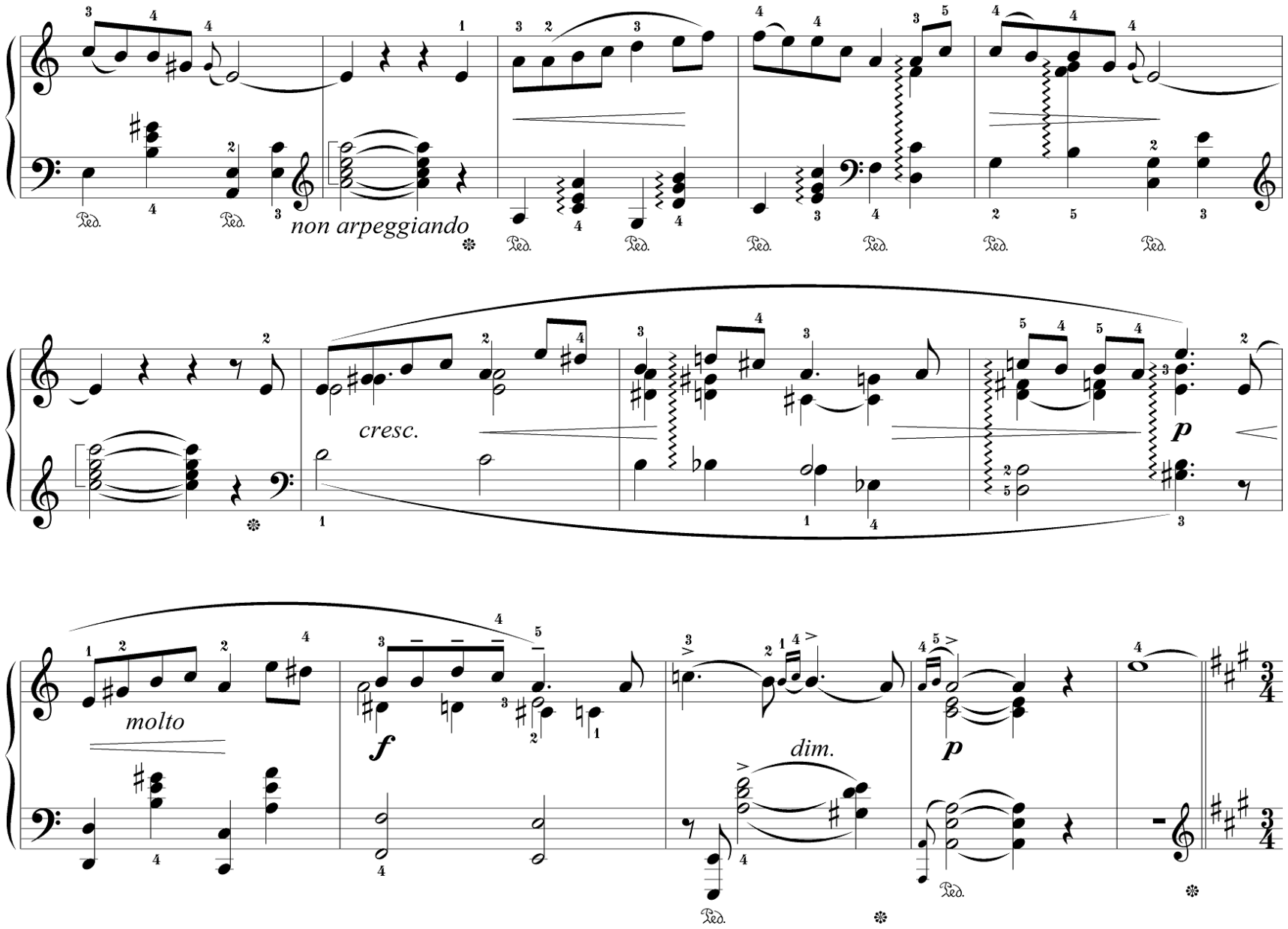
- A moving experience
  - Strong emotions: frisson, laughter, awe
- Expectation
  - Fulfillment: Reward
  - Violation: Surprise, laughter
- Tension, anticipation
  - Delayed resolution
  - Density of activity
- Prominence
  - Note-level variations
  - Vibrato and portamento
- Contrast
  - Section-level variations
  - Key change
- Time
  - Phrase-level variations
  - Tipping points
- Tension

Op. 52, No. 4

Edvard Grieg

Arr. for Piano by the Author



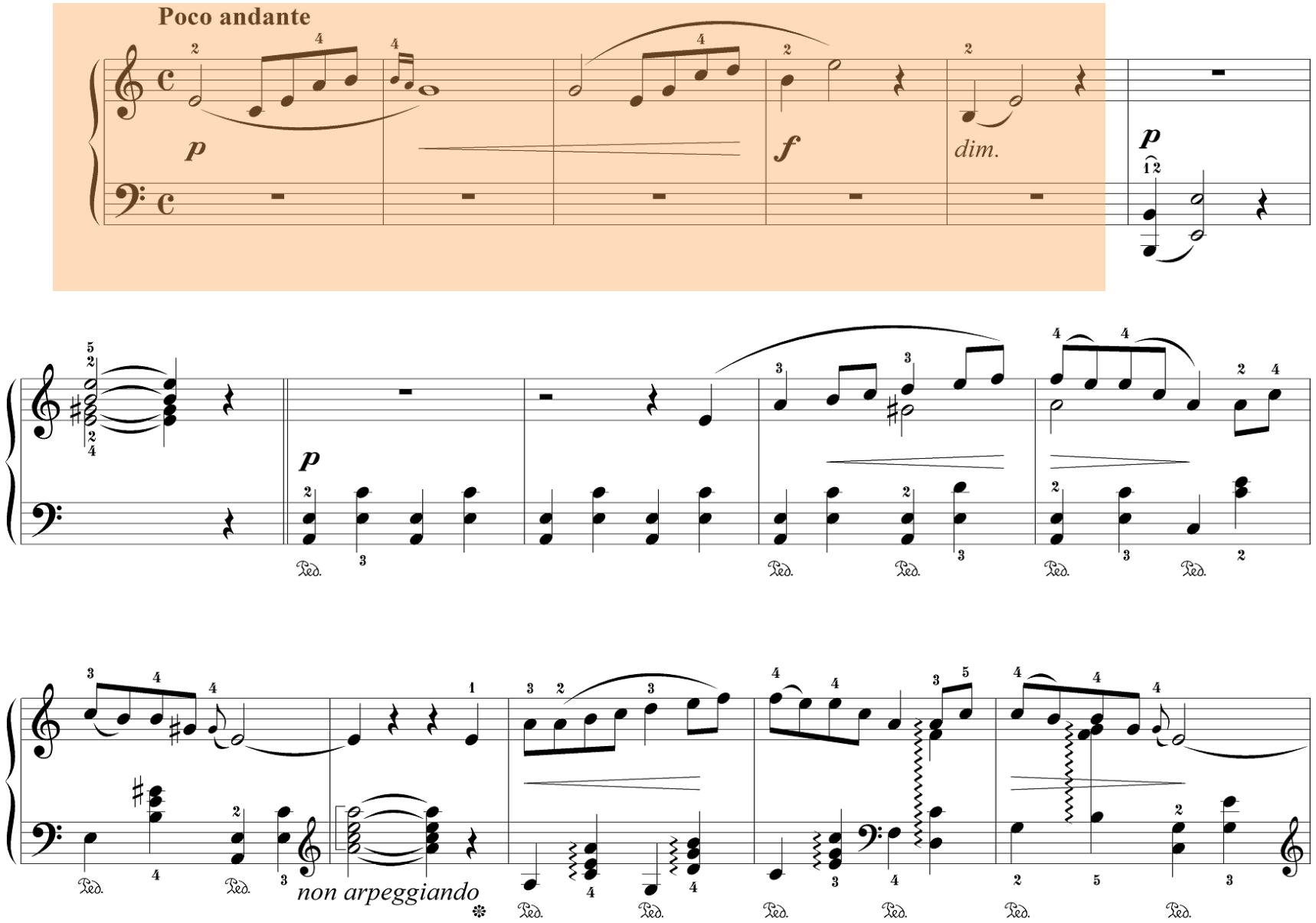


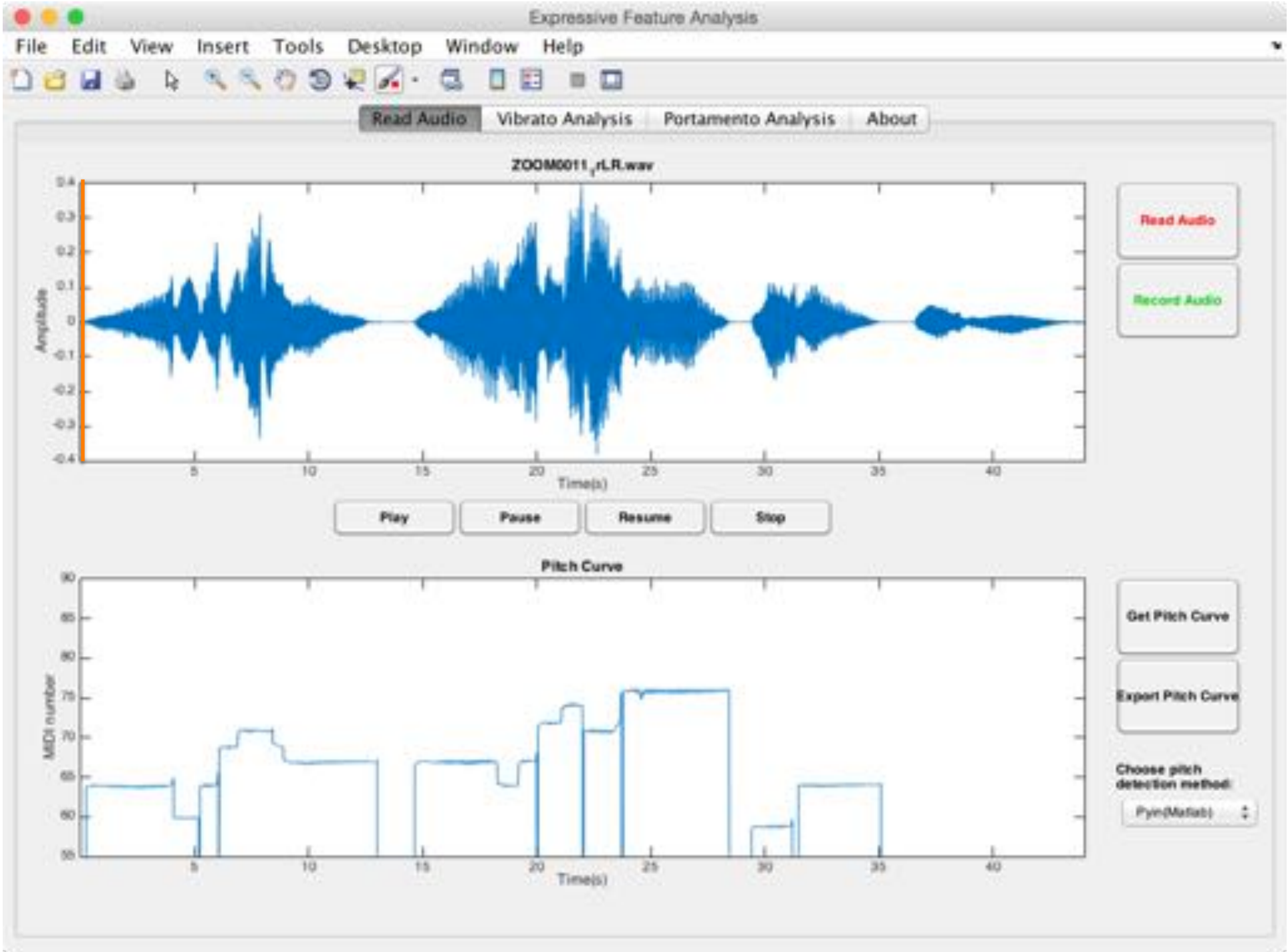
Prominence

Op. 52, No. 4

Edvard Grieg

Arr. for Piano by the Author

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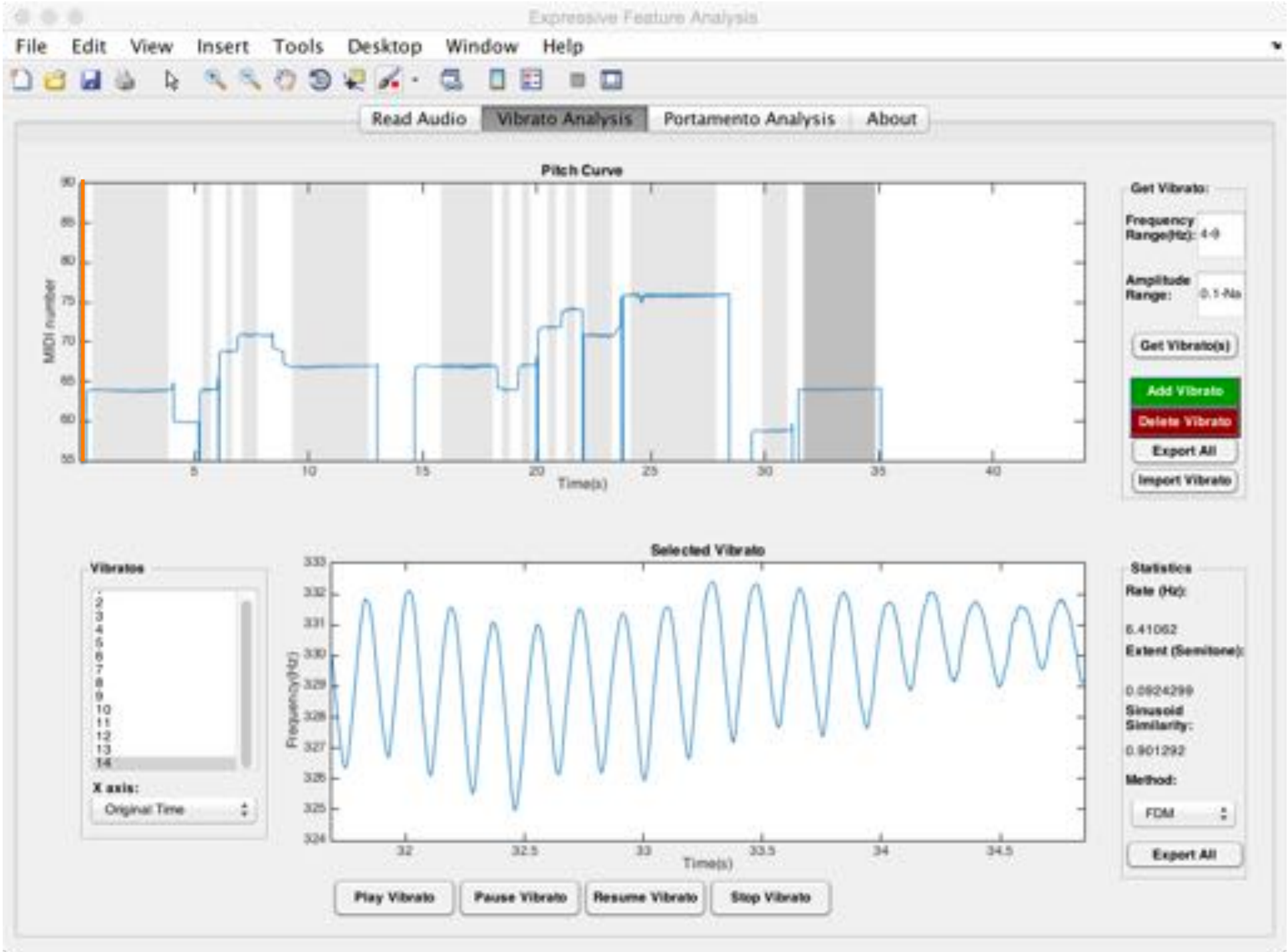
File Edit View Insert Tools Desktop Window Help
Read Audio
Vibrato Analysis
Portamento Analysis
About
ZOOM0011_rLR.wav
Amplitude
Time(s)
Read Audio
Record Audio
Play
Pause
Resume
Stop
Pitch Curve
MIDI number
Time(s)
Get Pitch Curve
Export Pitch Curve
Choose pitch detection method:
Pyin(Matlab)


Expressive Feature Analysis
File Edit View Insert Tools Desktop Window Help
Read Audio
Vibrato Analysis
Portamento Analysis
About
Pitch Curve
MIDI number
Time(s)
Get Vibrato:
Frequency Range(Hz):
Amplitude Range:
Get Vibrato(s)
Add Vibrato
Delete Vibrato
Export All
Import Vibrato
Vibratos
X axis:
Original Time
Selected Vibrato
Frequency(Hz)
Time(s)
Statistics
Rate (Hz):
6.41062
Extent (Semitone):
0.0924299
Sinusoid Similarity:
0.901292
Method:
FDM
Export All
Play Vibrato
Pause Vibrato
Resume Vibrato
Stop Vibrato

Portamento

Prominence

Vibrato

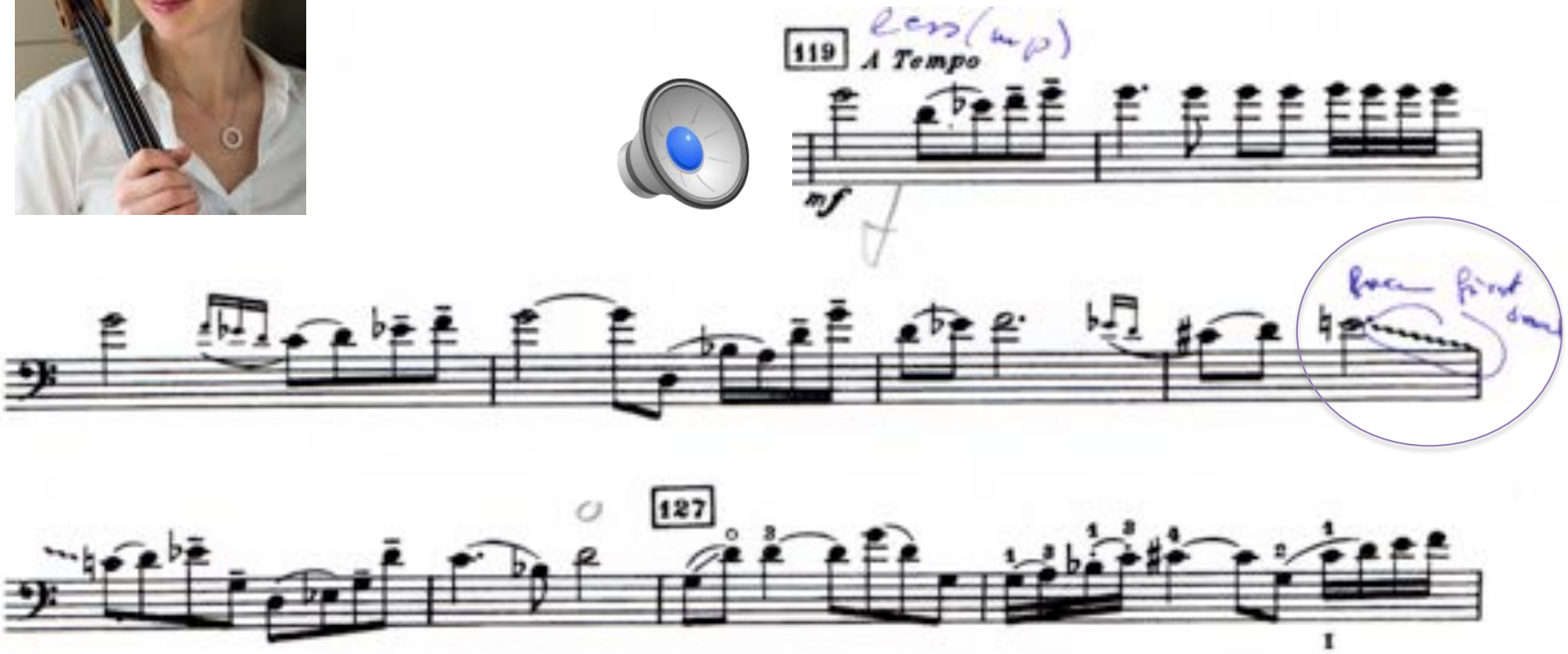
Le Grand Tango by Astor Piazzolla

– Ian Pressland & EC

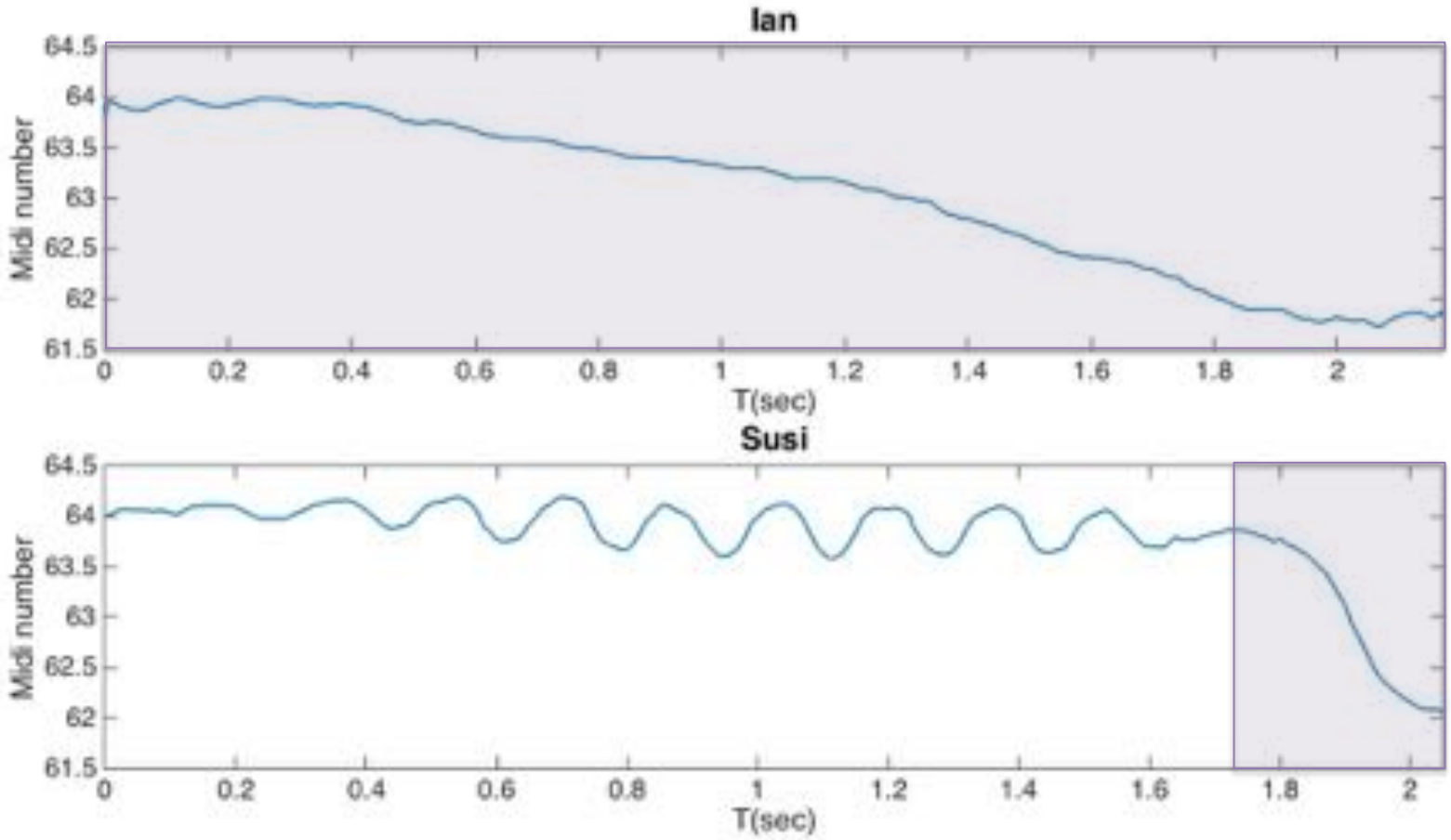
Le Grand Tango by Astor Piazzolla

– Ian Pressland & EC

– **Susanne Beer** & EC



Portamenti models

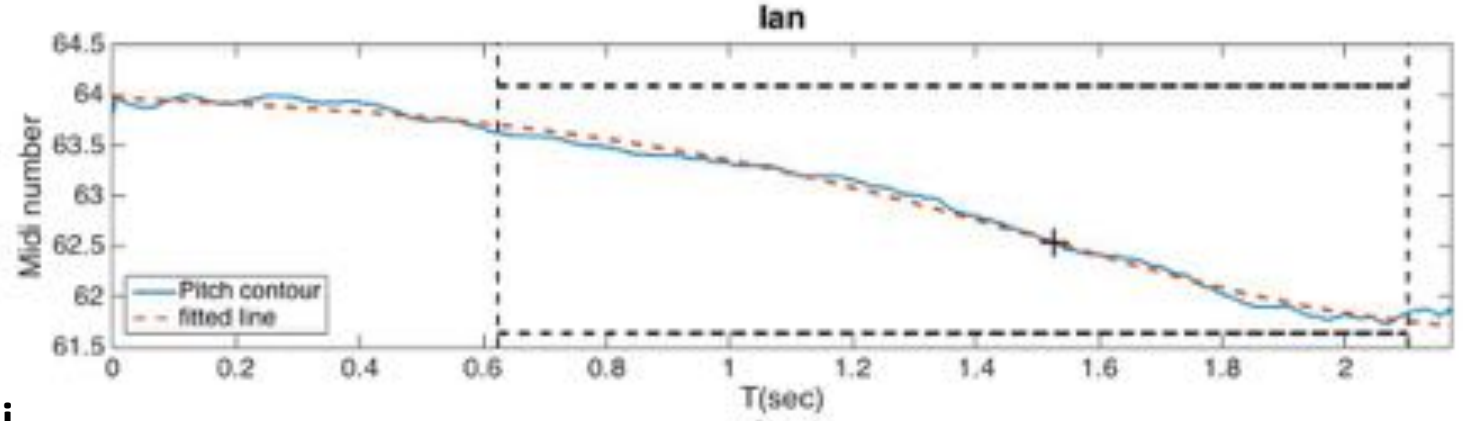


Yang & Chew 2015

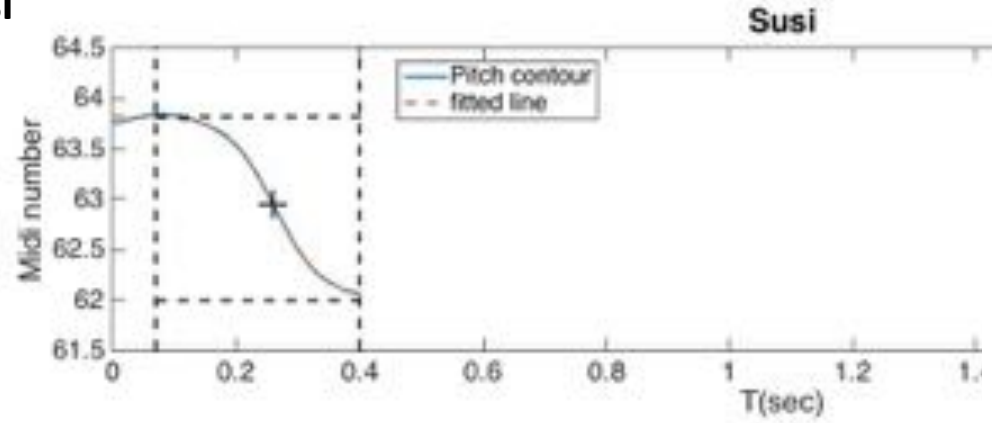
Logistic modeling of portamentos

Growth = -1.952
Duration = 1.48s
Interval = 2.45 semitones
Normalized Inflection time: 0.6105
Normalized Inflection pitch: 0.3687

Ian

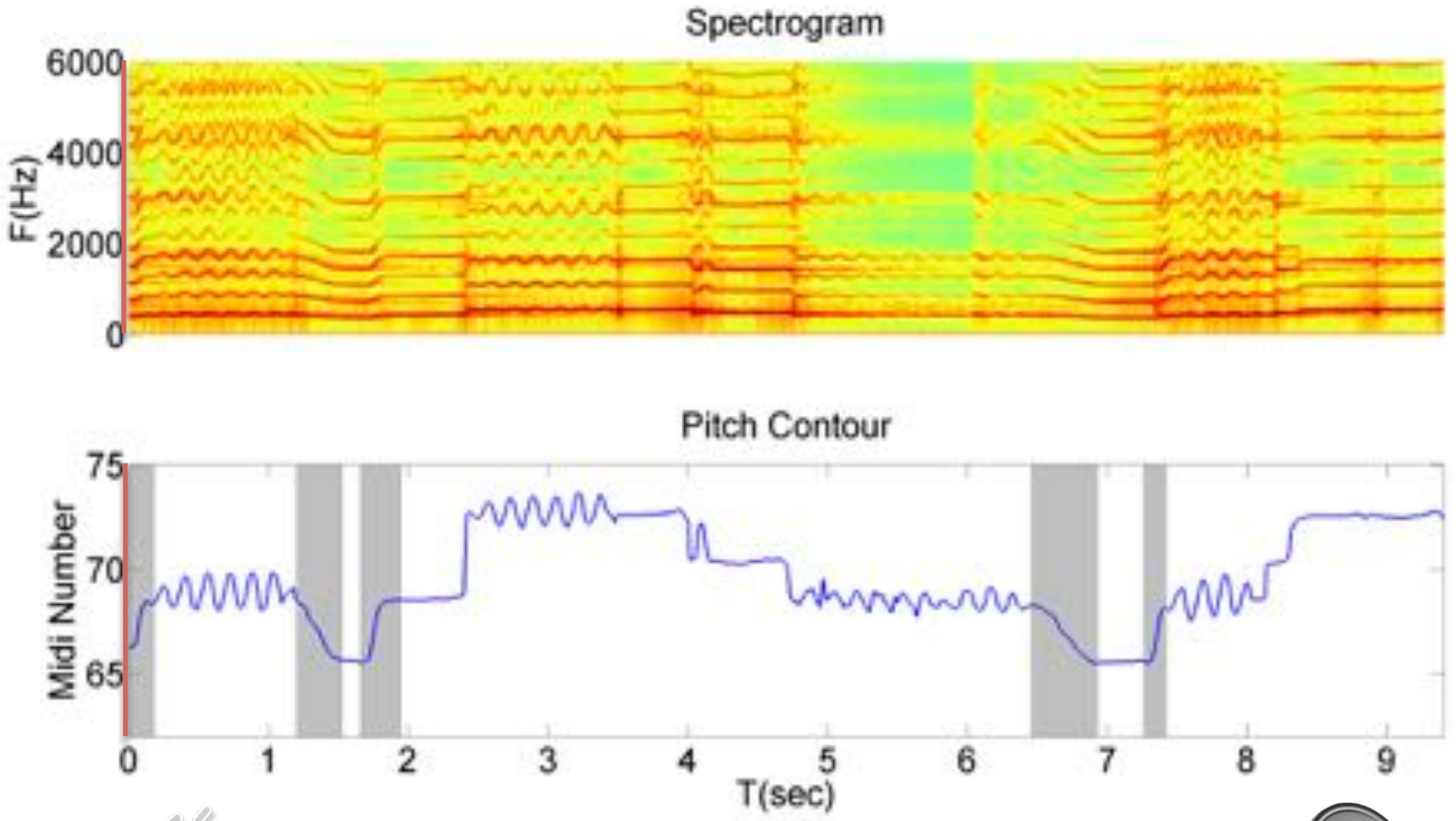


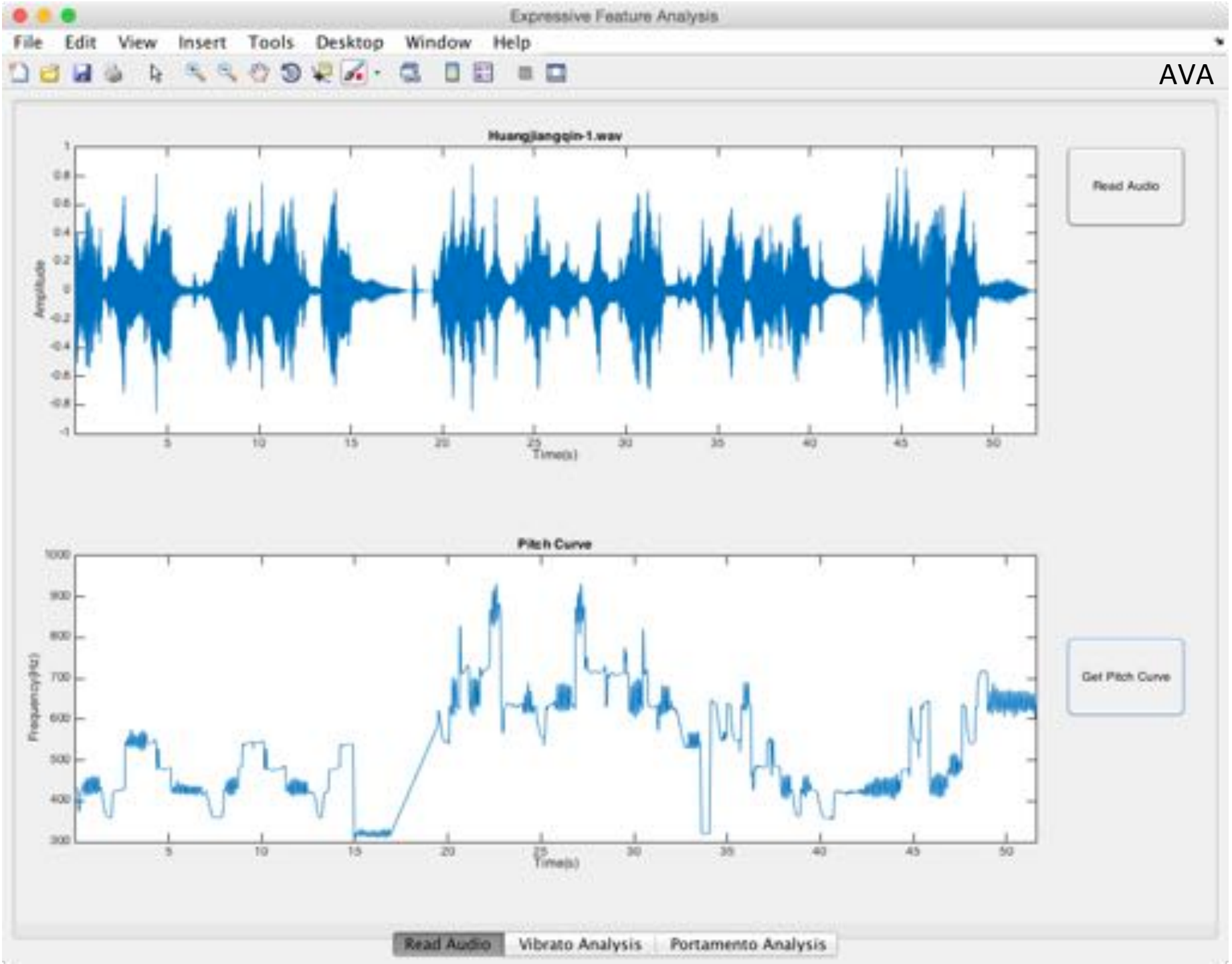
Susi



Growth = -28.28
Duration = 0.33s
Interval = 1.82 semitones
Normalized Inflection time: 0.5204
Normalized Inflection pitch: 0.5747

Portamenti in an erhu performance

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Huangjiangqin-1.wav
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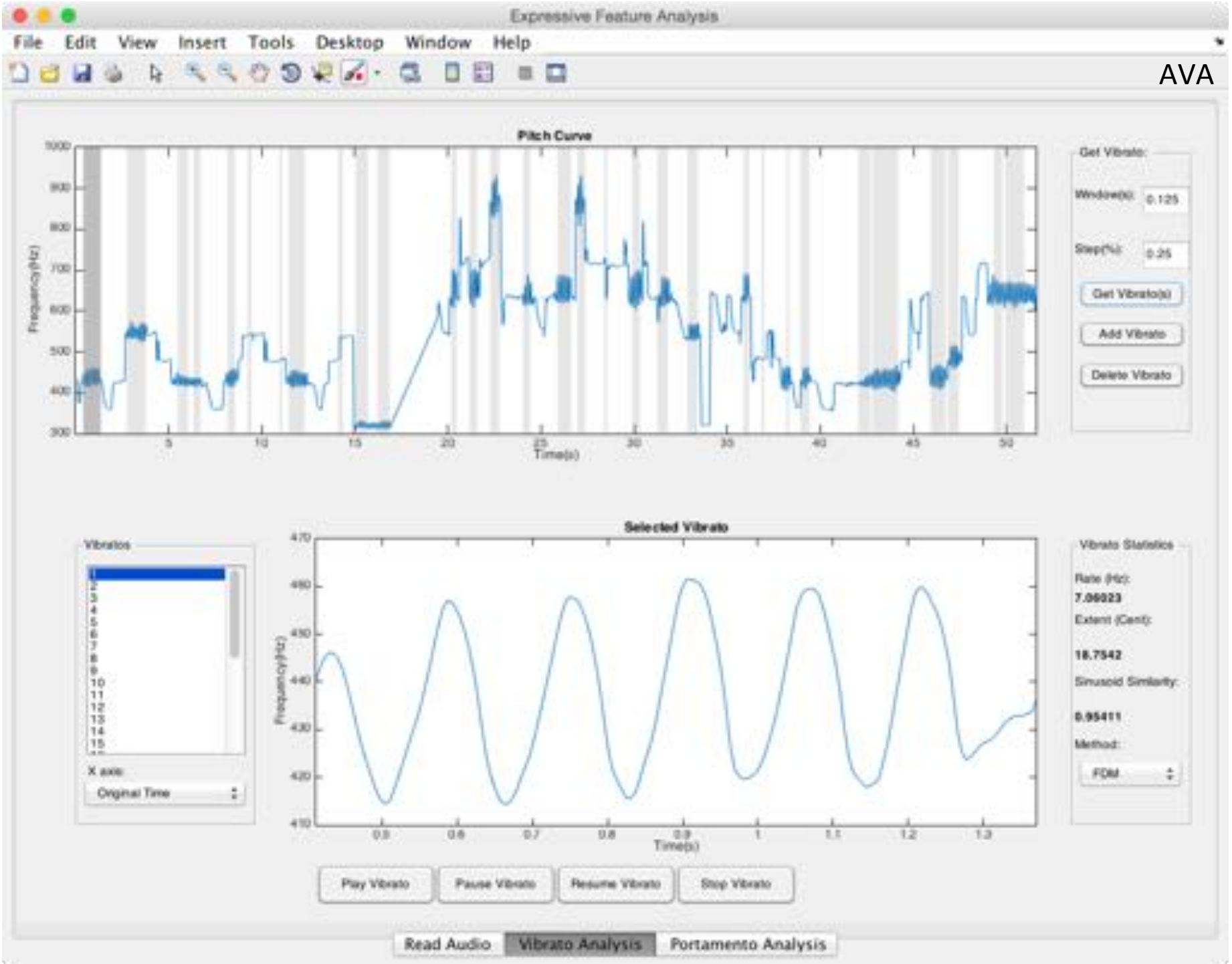
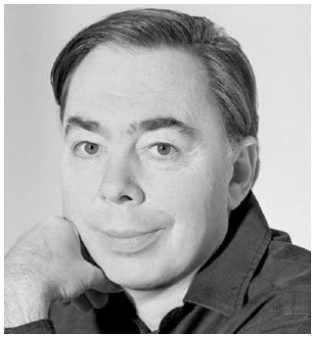
Time(s)
Read Audio
Pitch Curve
Frequency(Hz)
Time(s)
Get Pitch Curve
Read Audio
Vibrato Analysis
Portamento Analysis


Expressive Feature Analysis
File Edit View Insert Tools Desktop Window Help
AVA
Pitch Curve
Frequency(Hz)
Time(s)
Get Vibrato:
Window(s): 0.125
Step(%): 0.25
Get Vibrato(s)
Add Vibrato
Delete Vibrato
Vibratos
X axis:
Original Time
Selected Vibrato
Frequency(Hz)
Time(s)
Vibrato Statistics
Rate (Hz):
7.06023
Extent (Cent):
18.7542
Sinusoid Similarity:
0.95411
Method:
FDM
Play Vibrato
Pause Vibrato
Resume Vibrato
Stop Vibrato
Read Audio
Vibrato Analysis
Portamento Analysis

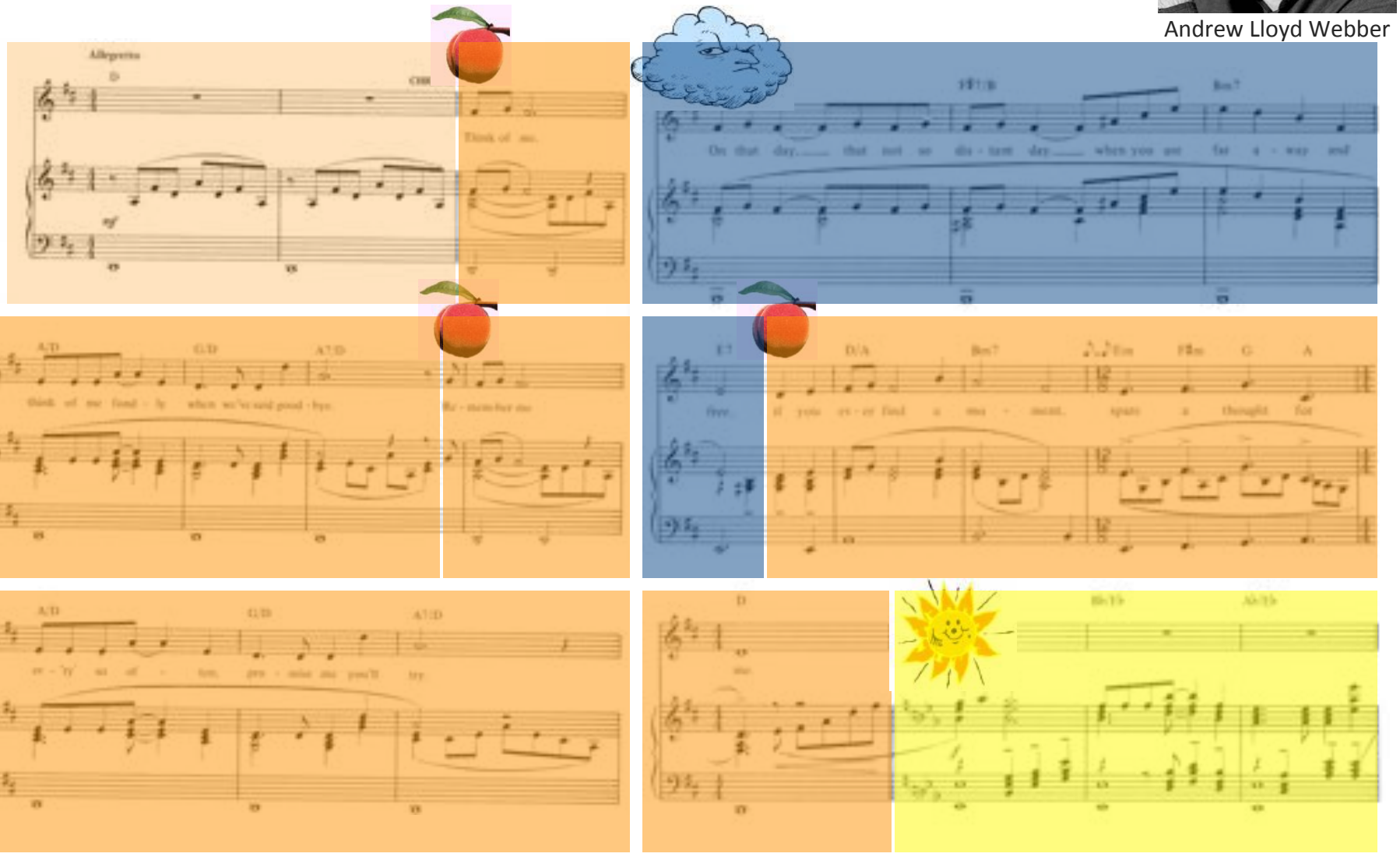
Luwei Yang, Khalid Rajab, Elaine Chew
luweiyang.com/research/ava-project

Contrast

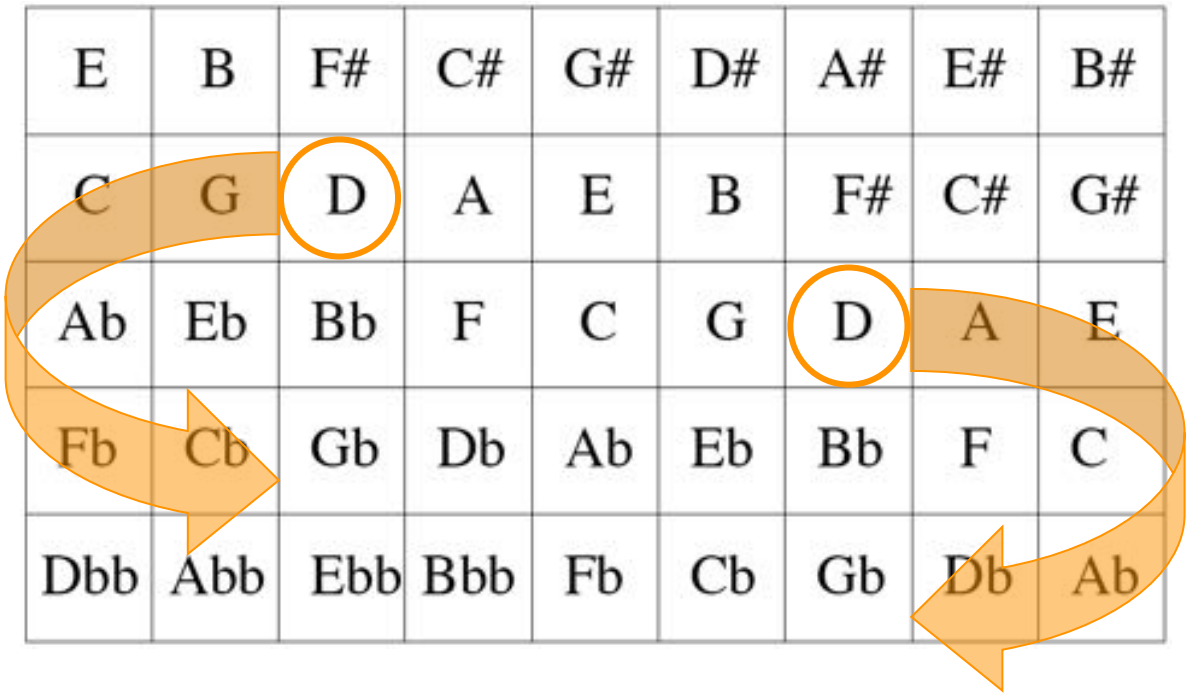
Think of Me



Andrew Lloyd Webber

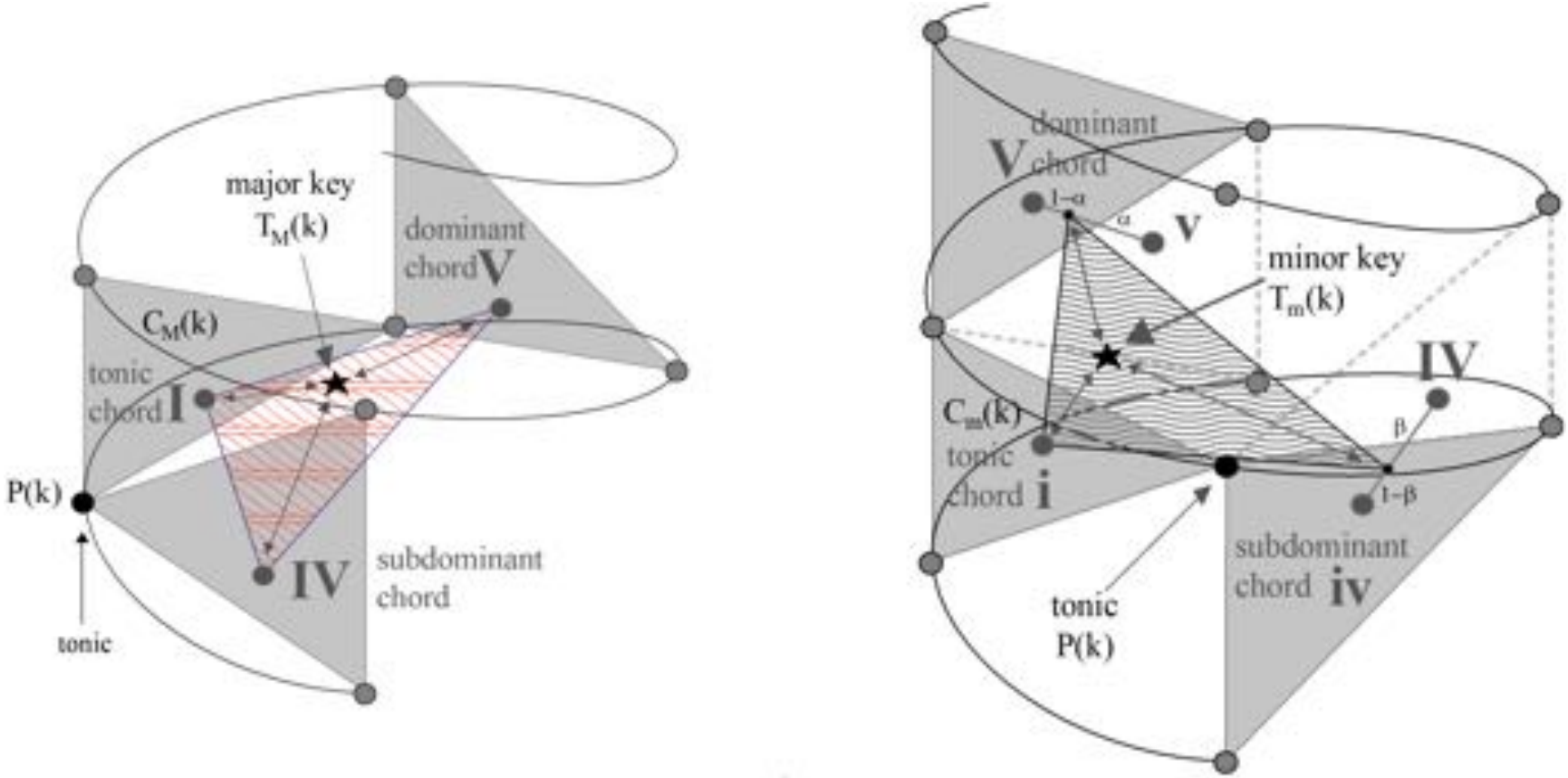


Spiral Array



Chew, E. (2000). Towards a Mathematical Model of Tonality.
Ph.D. dissertation. Operations Research Center, MIT. Cambridge, Massachusetts

Spiral Array

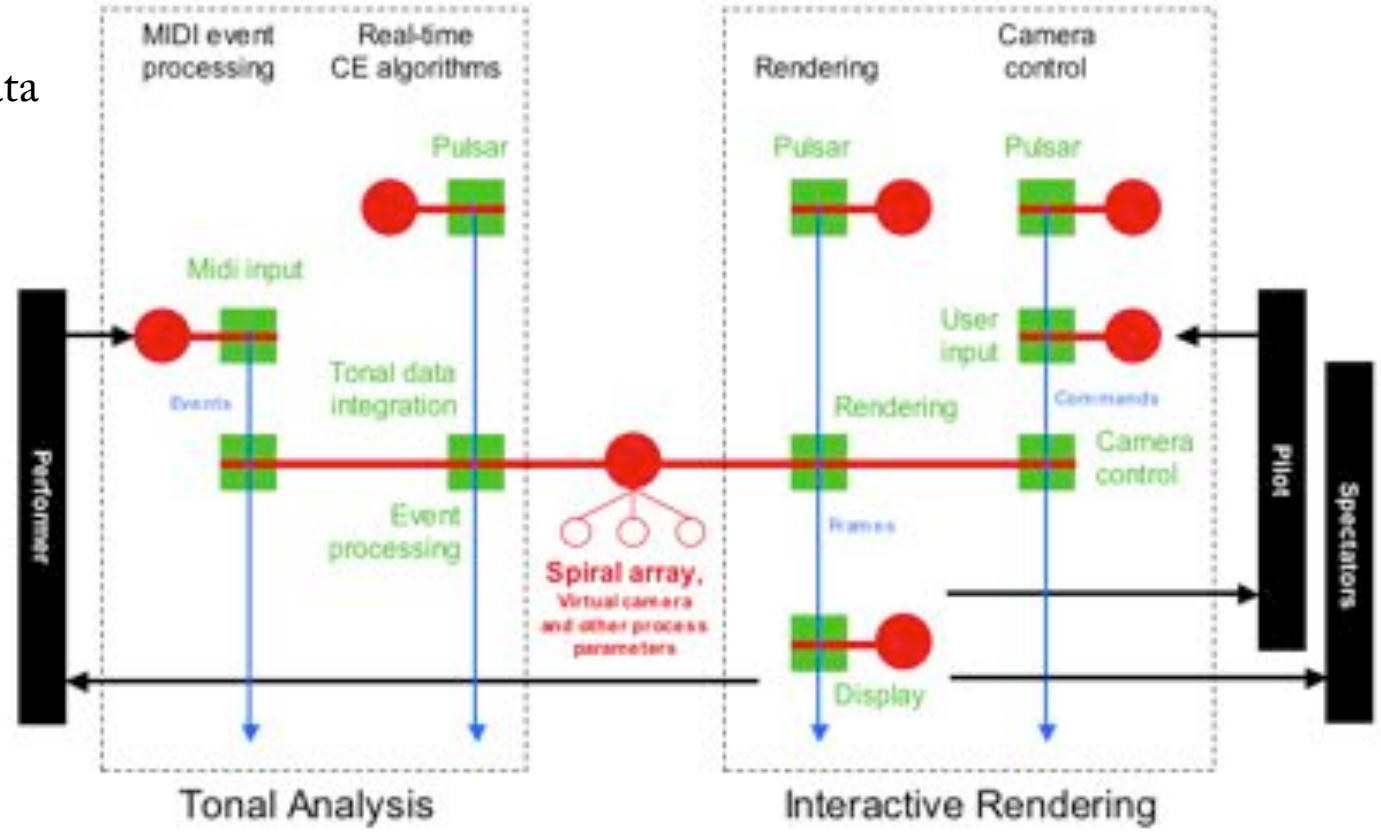


Chew, E. (2000). Towards a Mathematical Model of Tonality.
Ph.D. dissertation. Operations Research Center, MIT. Cambridge, Massachusetts

USC Video Channel - youtu.be/4GPwVNPuKuA

MuSA.RT: Software architecture

volatile vs.
persistent data

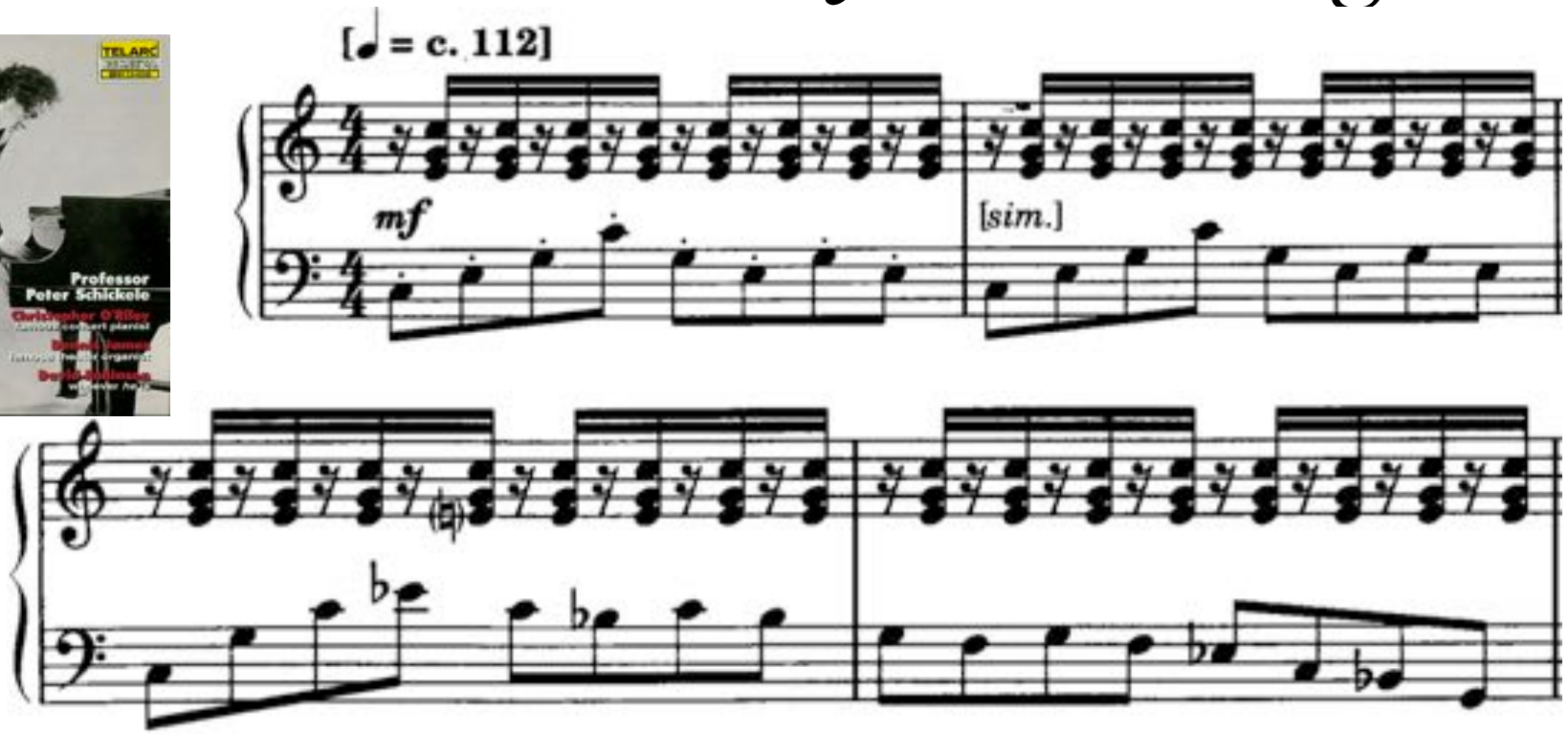


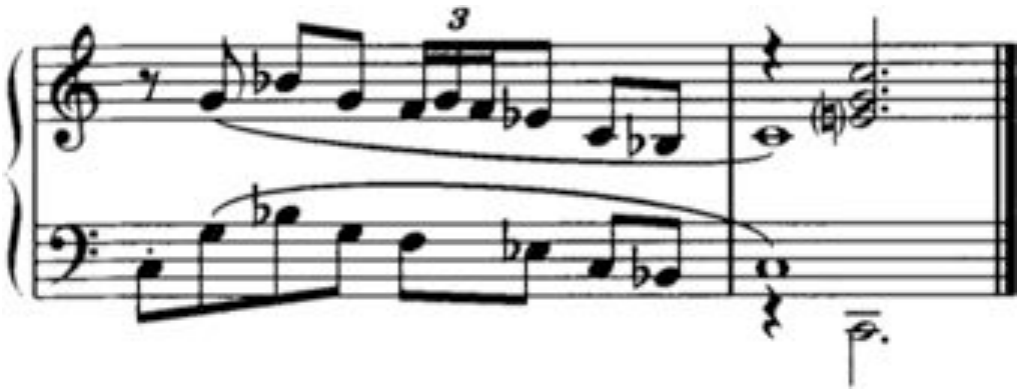
François, Alexandre R. J. (2009). Time and Perception in Music and Computation. In G. Assayag and A. Gerzso (eds.): New Computational Paradigms for Computer Music, Editions Delatour France / IRCAM, pp. 125-146.

Huron, D. (2006). Sweet Anticipation: Music and the psychology of expectation, Cambridge, MA: MIT Press.

PDQ Bach's Prelude No. 1 in C major

Expectations Violated: Jazz Ending





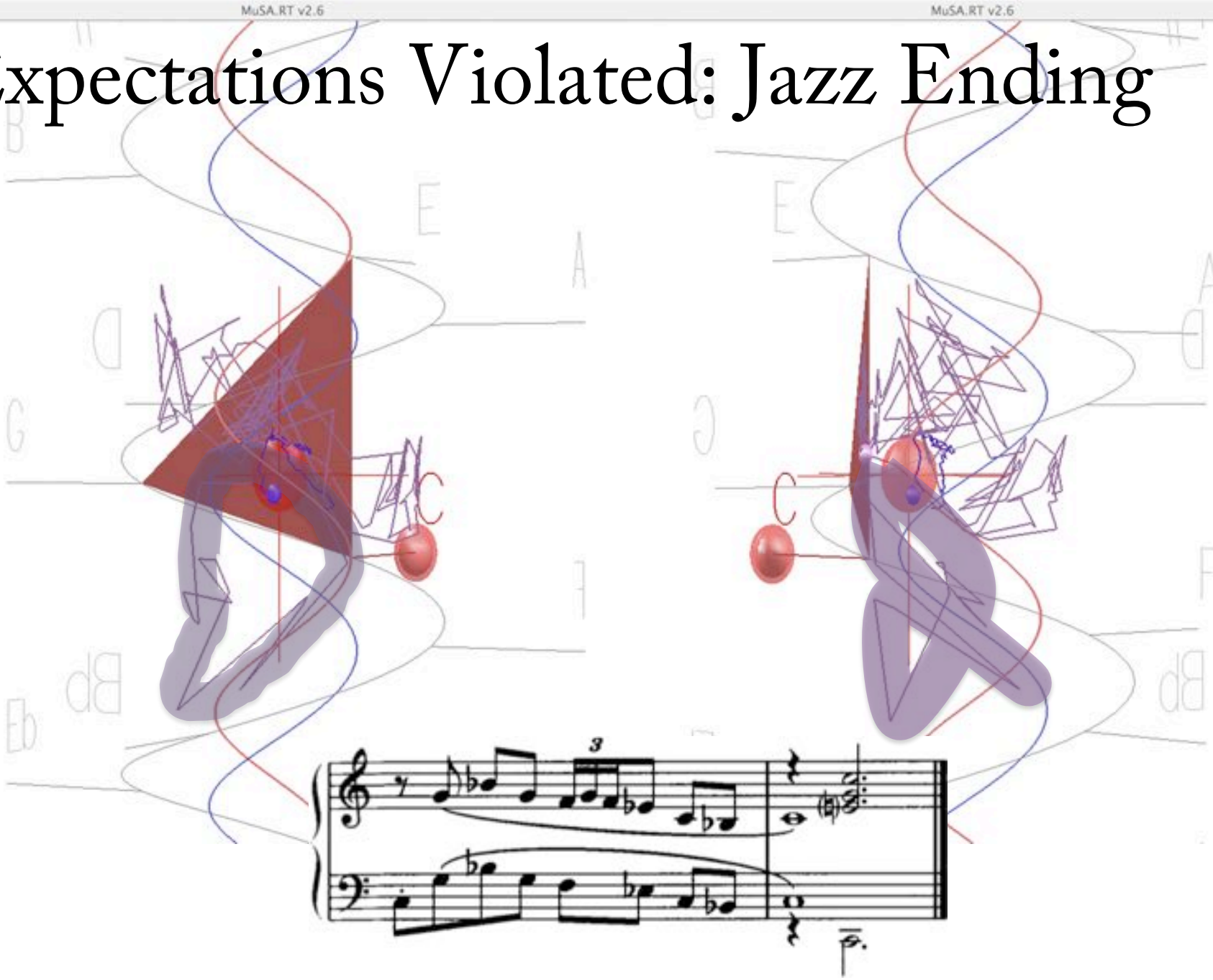
Chew, E. and A. R. J. François (2009). Visible Humour – Seeing P.D.Q. Bach's Musical Humour Devices in The Short-Tempered Clavier on the Spiral Array Space. In T. Klouche, T. Noll (eds.): Mathematics and Computation in Music, CCIS 37: 11-18, Berlin/Heidelberg: Springer

Humor

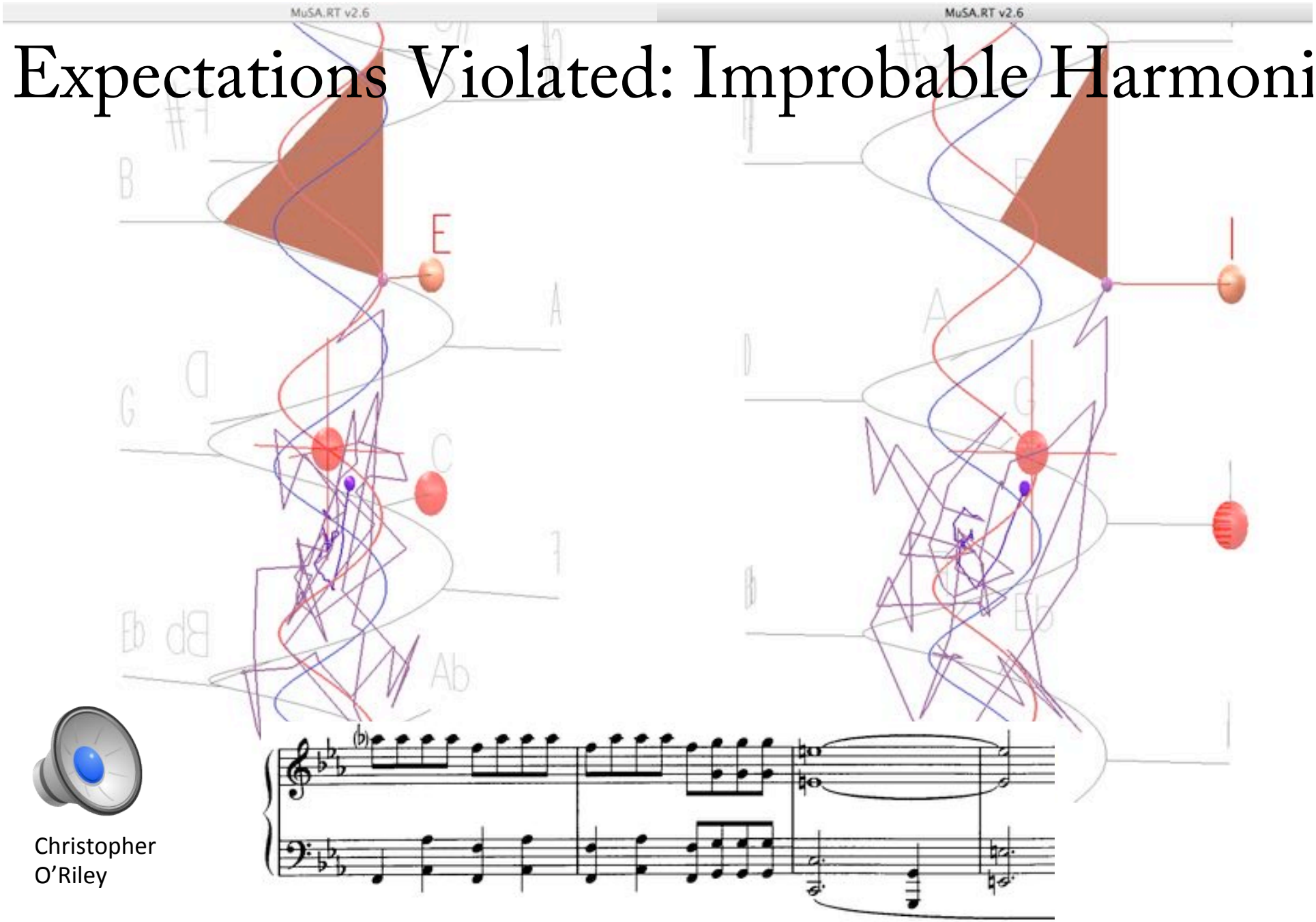
Contrast

Surprise

Expectations Violated: Jazz Ending



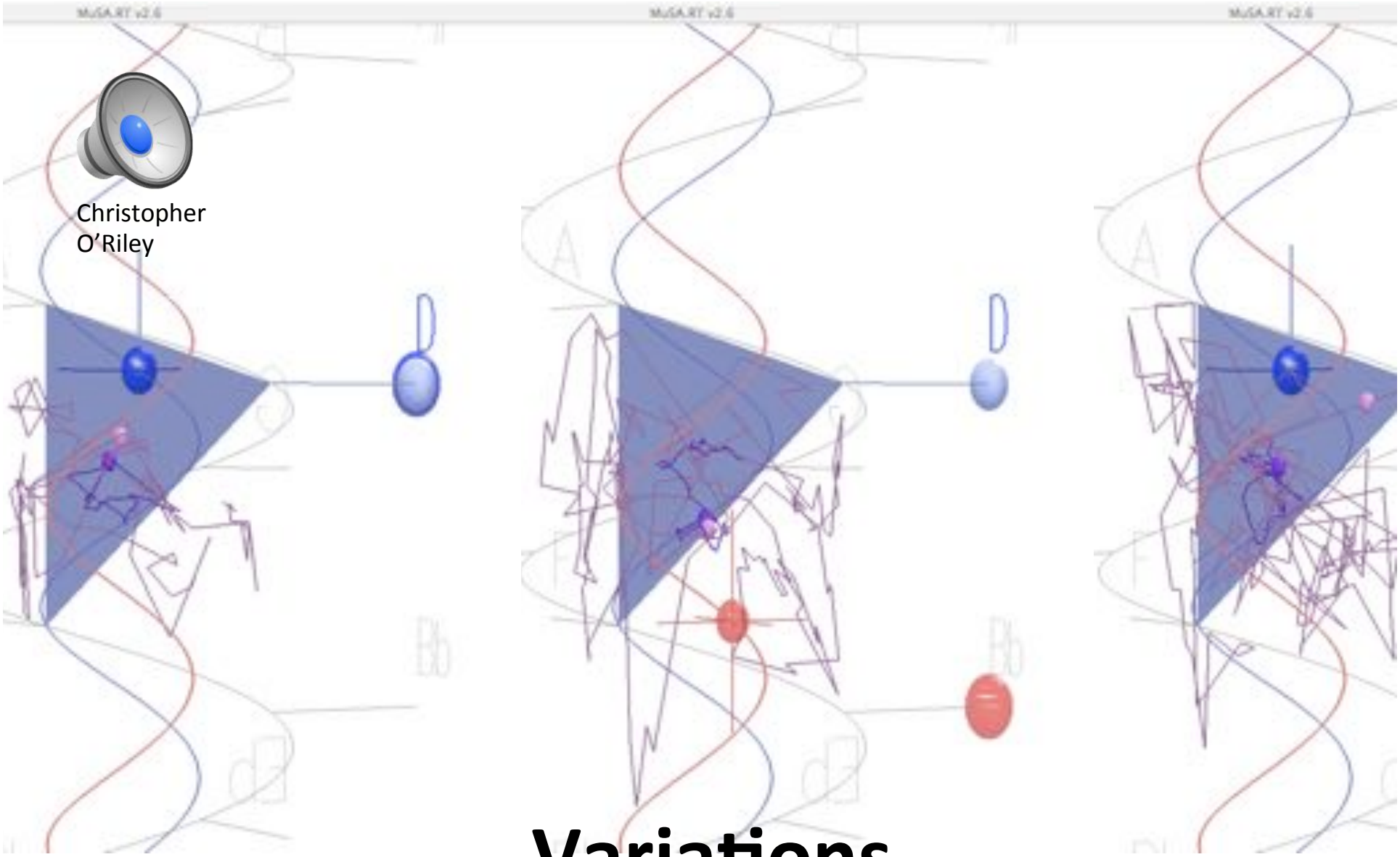
Expectations Violated: Improbable Harmoni



Christopher
O'Riley

Chew & François [MCM 2007]

Variations on a Theme: Prelude No. 5 in D minor: Theme (simple)



Christopher
O'Riley

Variations

Alexandre François and Elaine Chew

itunes.apple.com/us/app/musa-rt/id506866959?mt=12

International Series in Operations Research & Management Science ISOR 204

Elaine Chew

Mathematical and Computational Modeling of Tonality

Theory and Applications

I have watched with interest and appreciation as Elaine Chew's Spiral Array model has developed over the last 15 years. It is unique in representing pitches, intervals, chords, and keys in the same elegant geometric representation. In this way, the model addresses the fundamental problem of how to represent the hierarchical nature of tonal listening. The monograph presents in-depth analyses of a wide variety of interesting musical examples as well as large-scale, quantitative tests of algorithms for key-finding, pitch spelling, and musical segmentation. The reader will be amply rewarded with mathematical and musical insights – and intrigued by the power of mathematics to reveal the inner workings of music cognition.

– Carol Lynne Krumhansl, Professor of Psychology Cornell University

"What do you mean by key?" The seemingly innocent question asked once to the author by a student initiates a fascinating scientific journey into the concept of tonality addressed through its cognitive, mathematical and computational ramifications. This essential yet accessible and entertaining book results from years of research and experimentation by one of today's prominent minds in music science, with the right balance of formal modelling, experimentation and musical knowledge, always situated in the history of ideas. The student and the professional in computation and music related domains will benefit greatly from reading this book, as well as the music lover interested in reflecting on the way we apprehend tonality.

– Gerard Assayag, Research Director, Sciences and Technologies for Music and Sound Laboratory (IRCAM, CNRS, and Pierre et Marie Curie University)

From its imaginative opening pages to its rigorous appendices, Chew's book takes the reader on an engrossing tour through the theory and applications of her ingenious multiple-helix model of musical tonality. She approaches music theory and cognition from a fresh perspective inspired by operations research, to great advantage. One comes away with the clear sense that this approach will continue to bear fruit, whether through elaboration of the underlying model or through discovery of its applicability to new practical problems. No one interested in pitch representation, computational music analysis, or music visualization should miss this important volume.

– Douglas Keislar, Editor, Computer Music Journal (MIT Press)

Business/Economics

ISBN 978-1-4614-9474-4

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Chew

Mathematical and Computational Modeling of Tonality

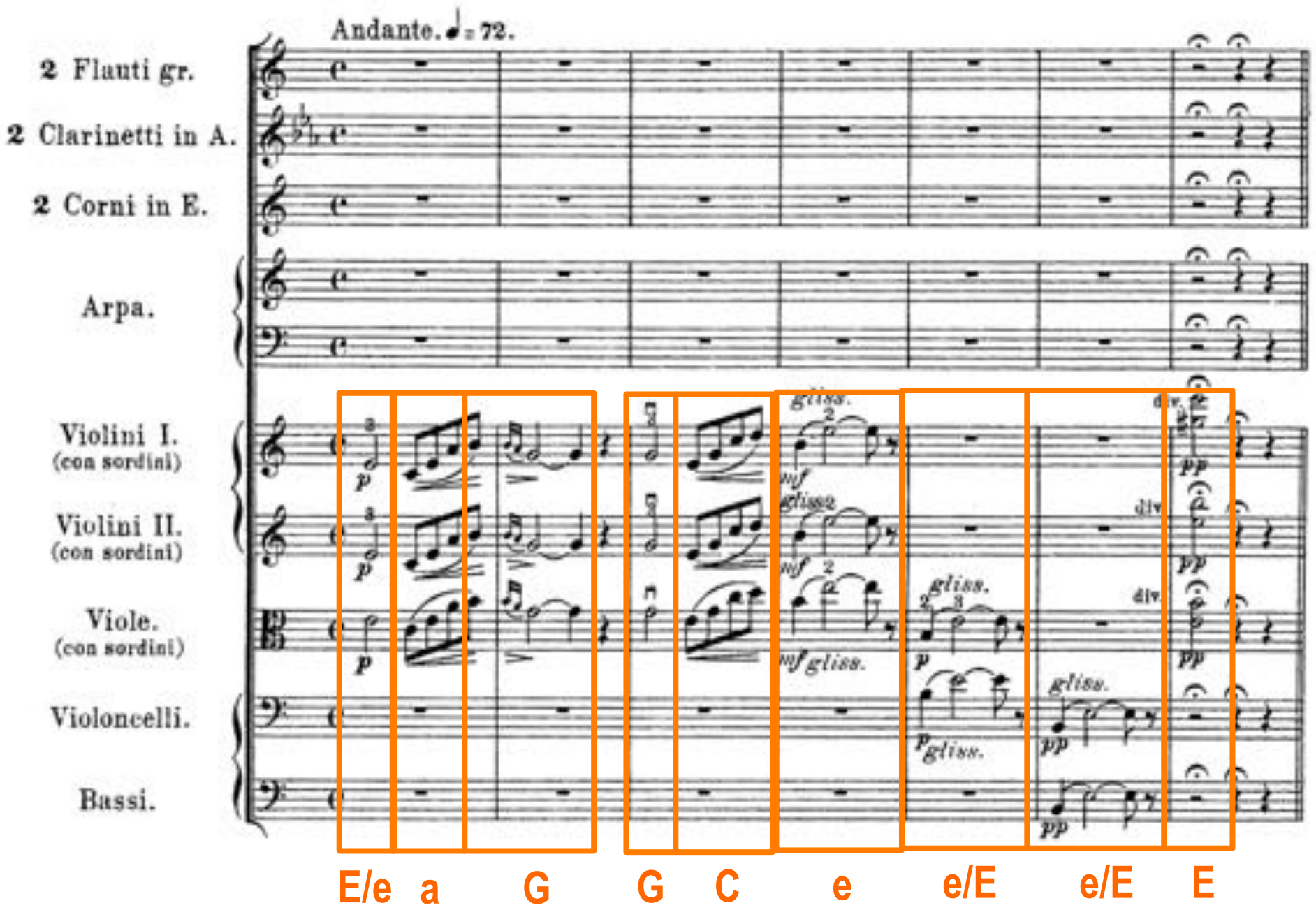
International Series in
Operations Research & Management Science

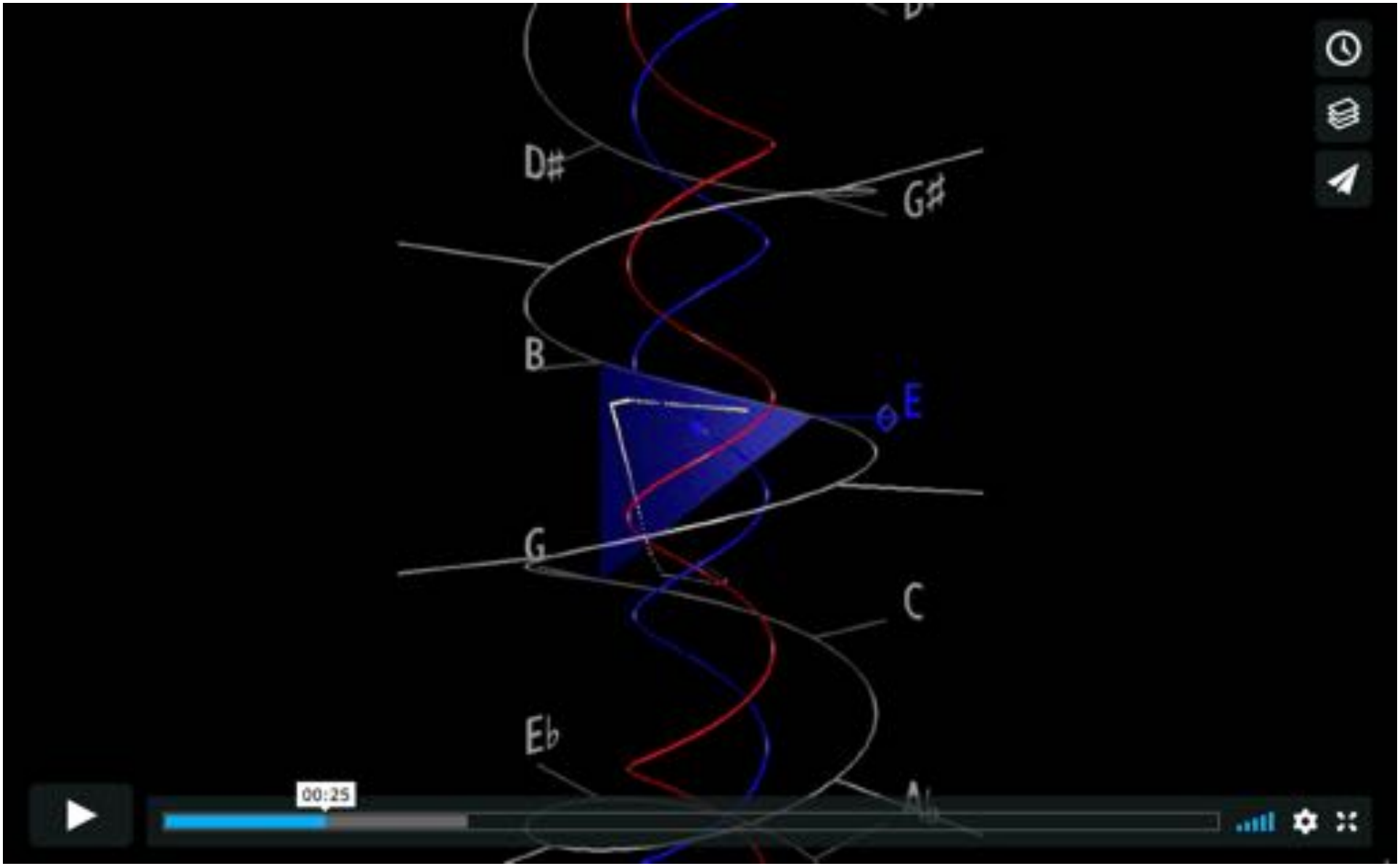
Elaine Chew

Mathematical and Computational Modeling of Tonality

Theory and Applications

Springer


Andante. ♩ = 72.
2 Flauti gr.
2 Clarinetti in A.
2 Corni in E.
Arpa.
Violini I.
(con sordini)
Violini II.
(con sordini)
Viole.
(con sordini)
Violoncelli.
Bassi.
E/e
a
G
G
C
e
e/E
e/E
E



https://vimeo.com/195047764

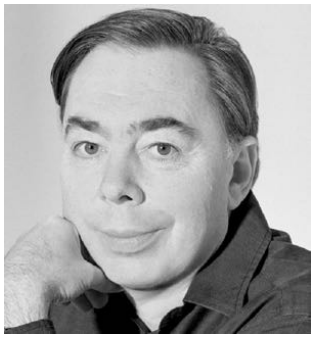
Humor

Tonal contrast

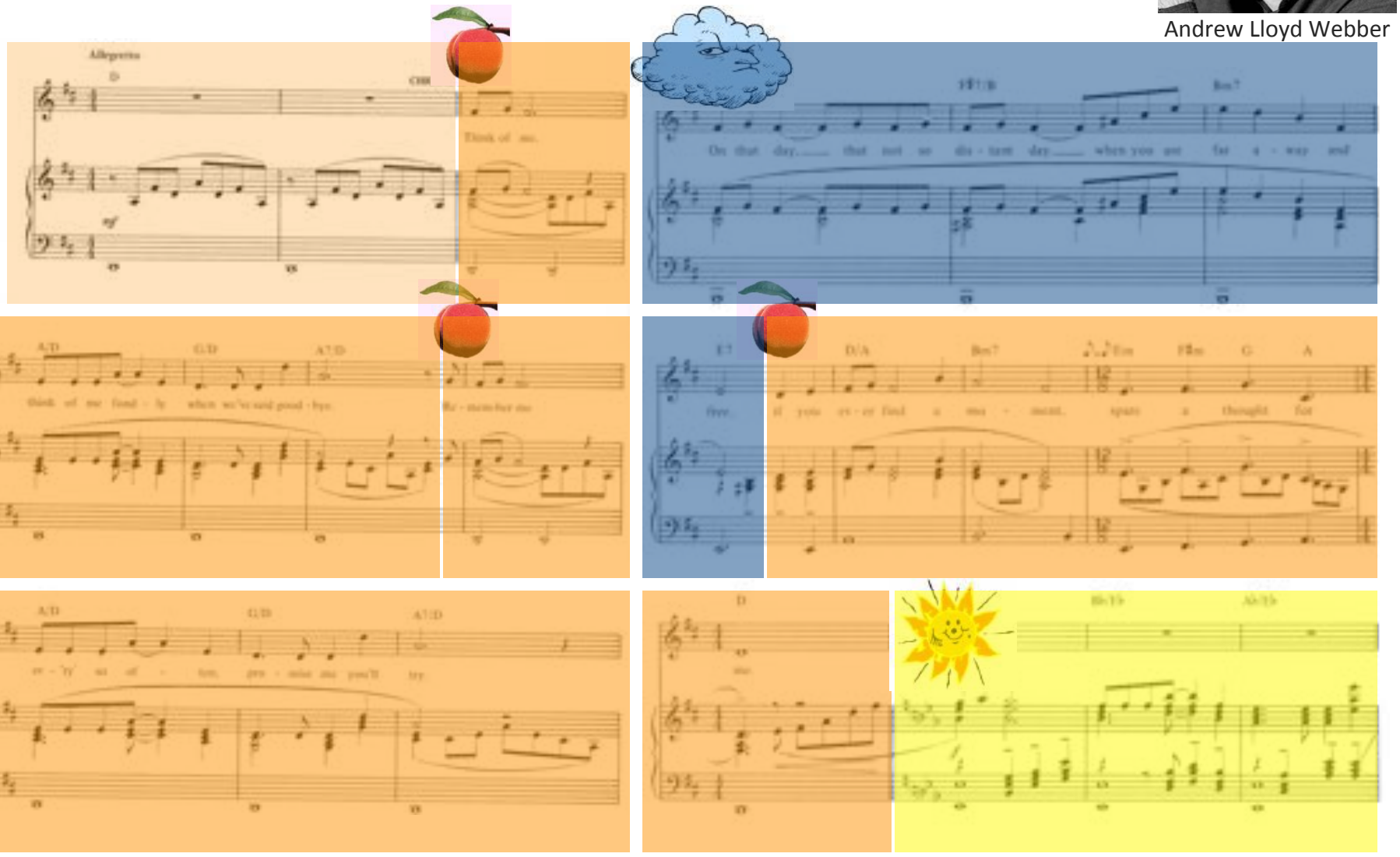
Contrast

Surprise

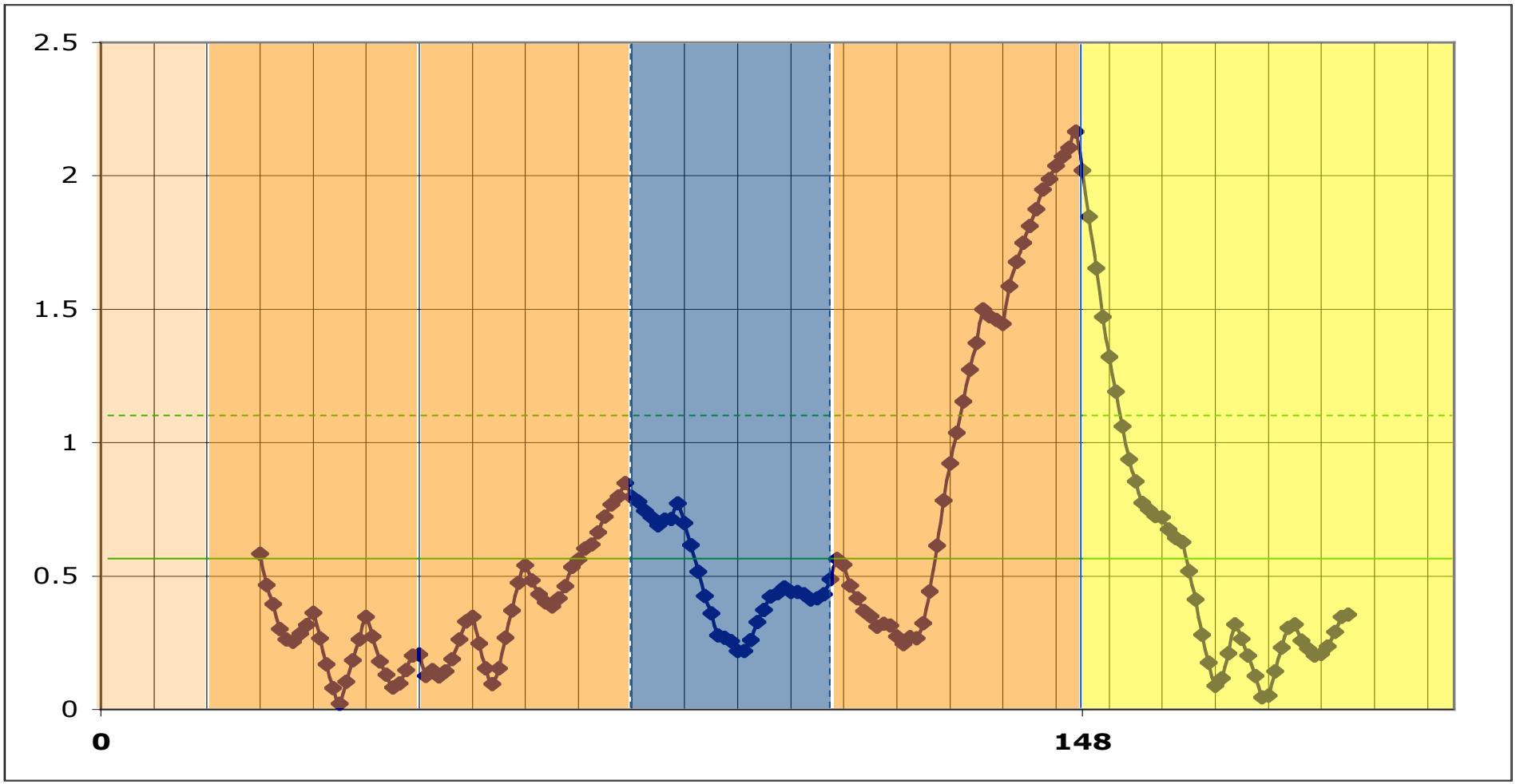
Think of Me



Andrew Lloyd Webber

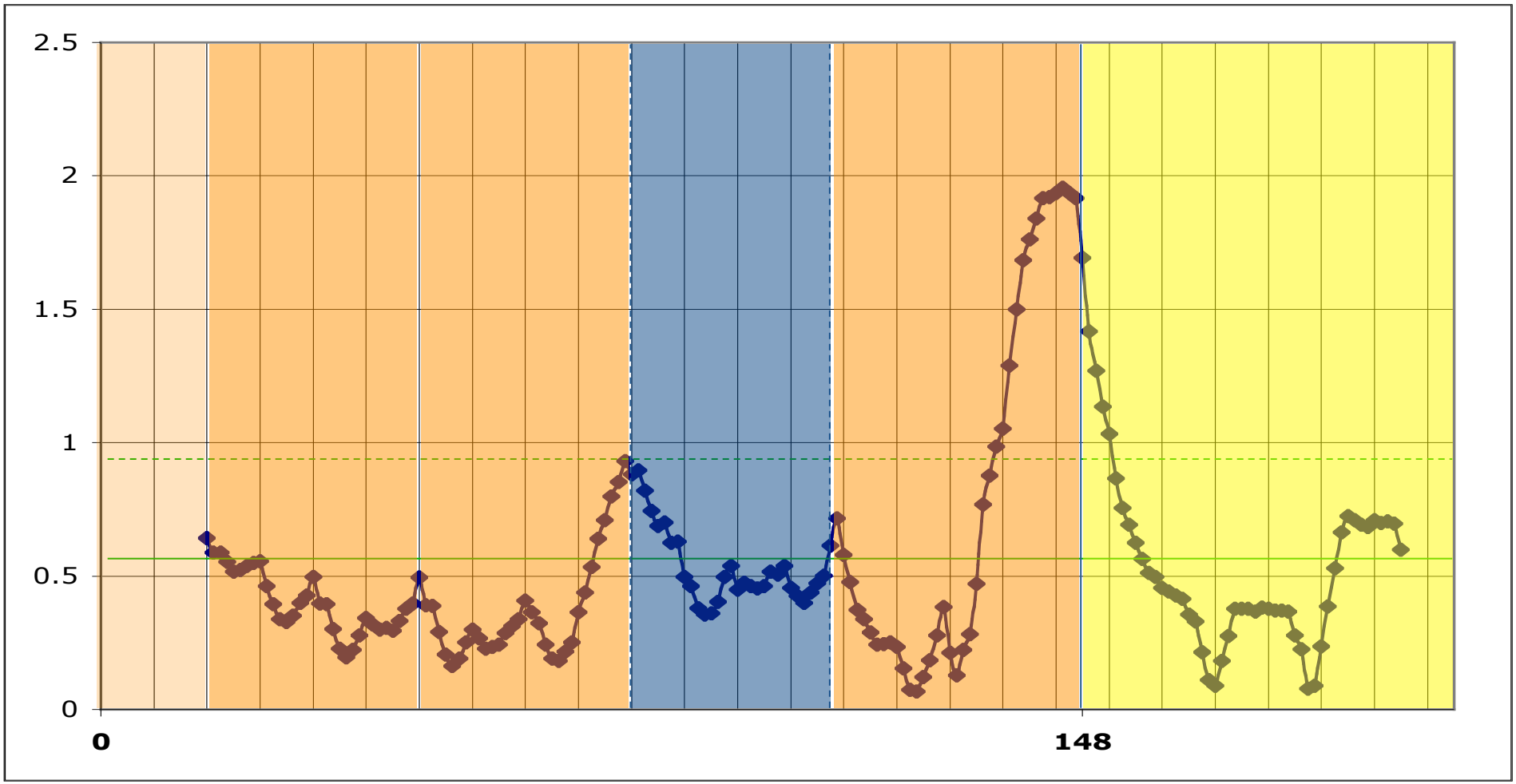


Tonal Contrast



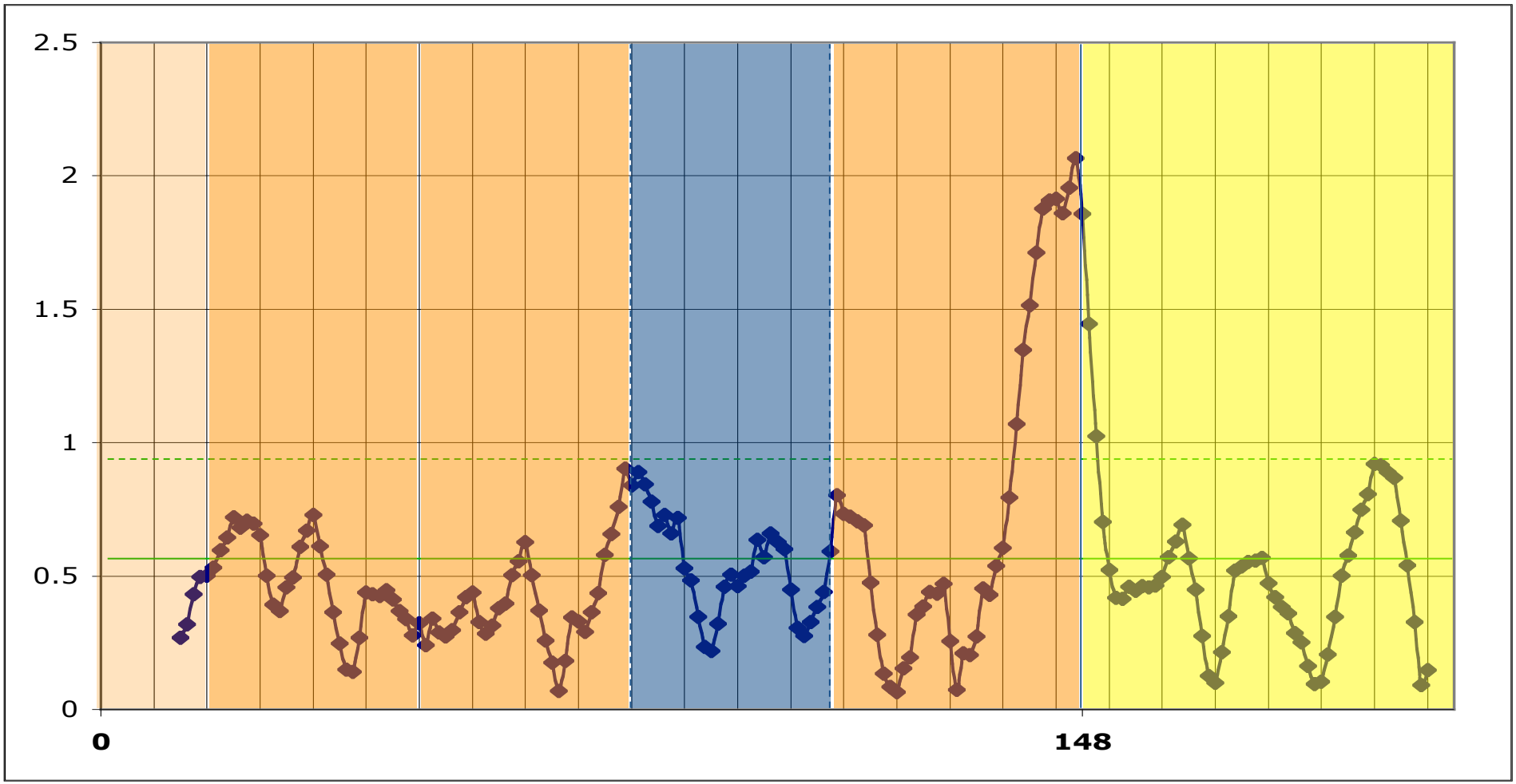
w=24 eighth notes (3 bars)

Tonal Contrast



w=16 eighth notes (2 bars)

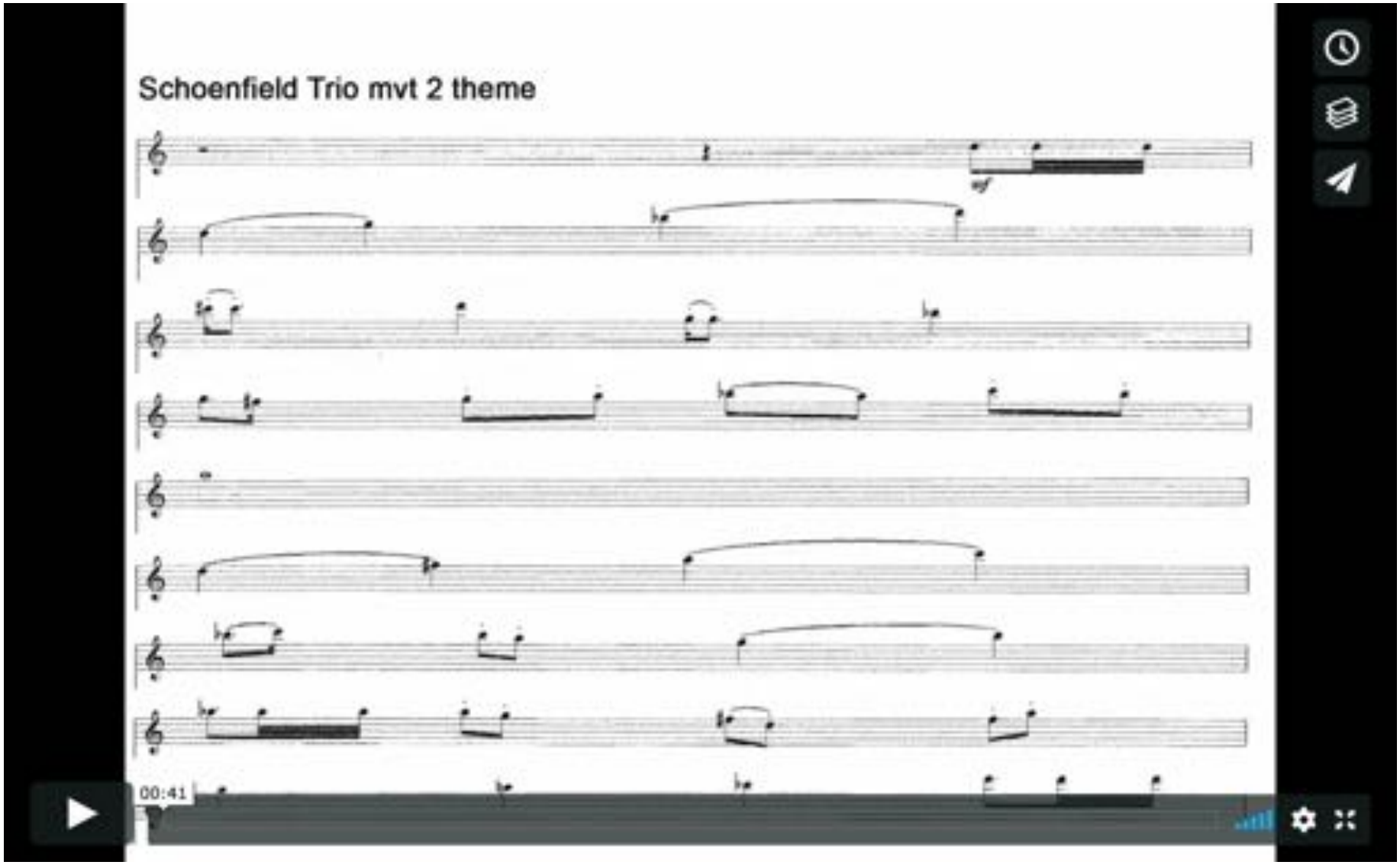
Tonal Contrast



w=12 eighth notes (1-1/2 bars)

Time

https://vimeo.com/151142022



Chew, E. (2016). Motion and Gravitation in the Musical Spheres. In J. B. L. Smith, E. Chew, G. Assayag (eds.): *Mathemusical Conversations: Mathematics and Computation in Music Performance and Composition*. London: Imperial College Press / NUS Institute for Mathematical Sciences Lecture Notes, World Scientific

Allegretto con moto

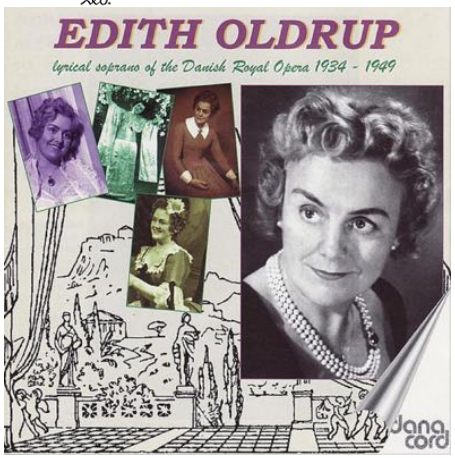
pp

dolciss.

pp

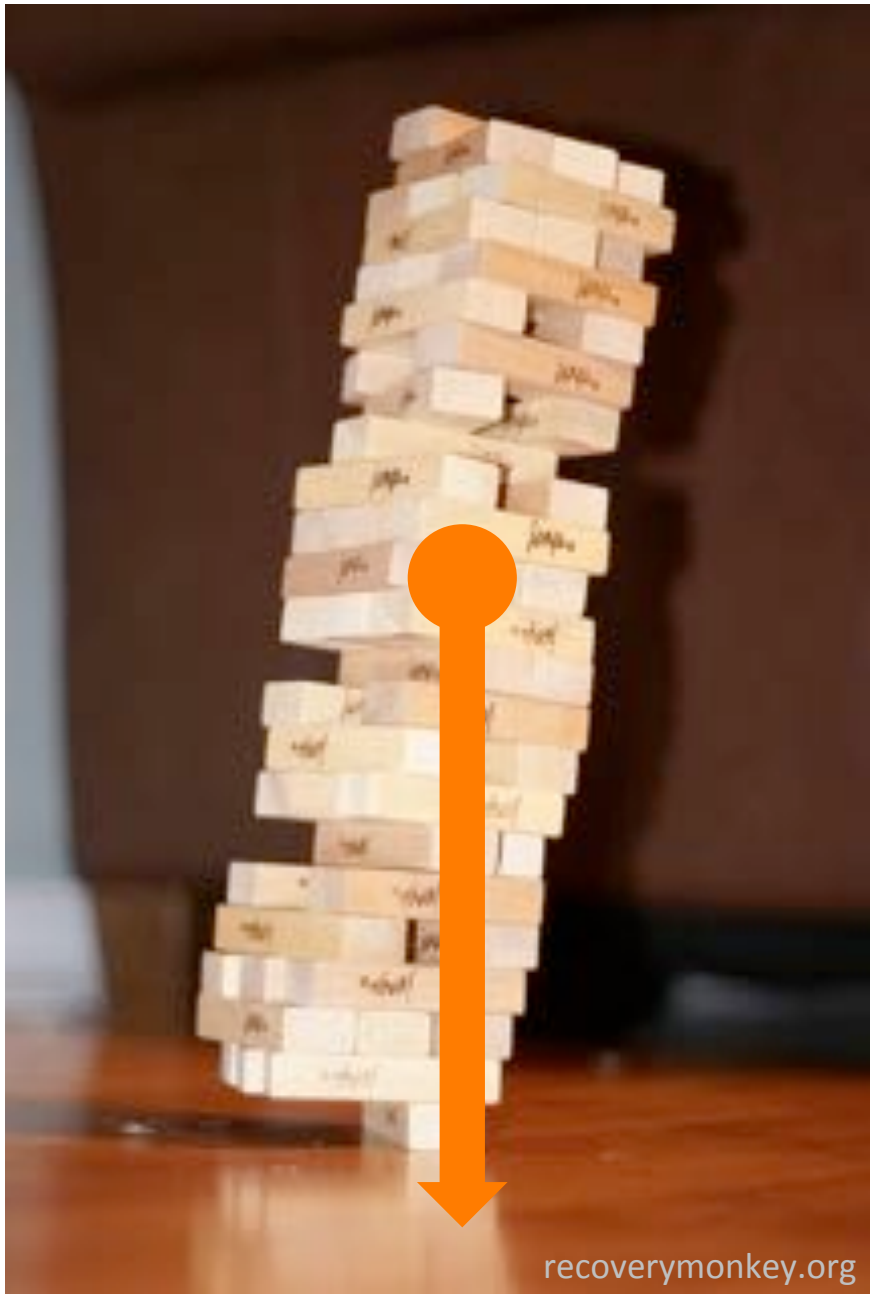
poco rit.

Tempo 1



Time

Tipping points



Physics: The point beyond which the line through the centre of gravity lies outside the base of the object.

youtu.be/RTNeHzzF8i8

Schon Rosmarin
by Kreisler

1936 version, with pianist
Franz Rupp

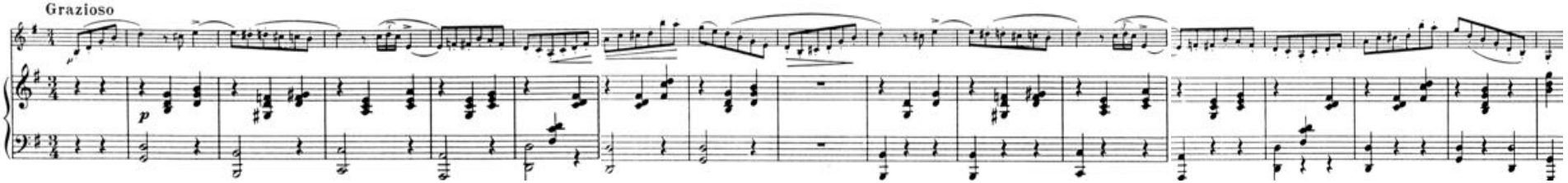
Kreisler plays Schon Rosmarin: Graph of crotchet note length vs. crotchet note number

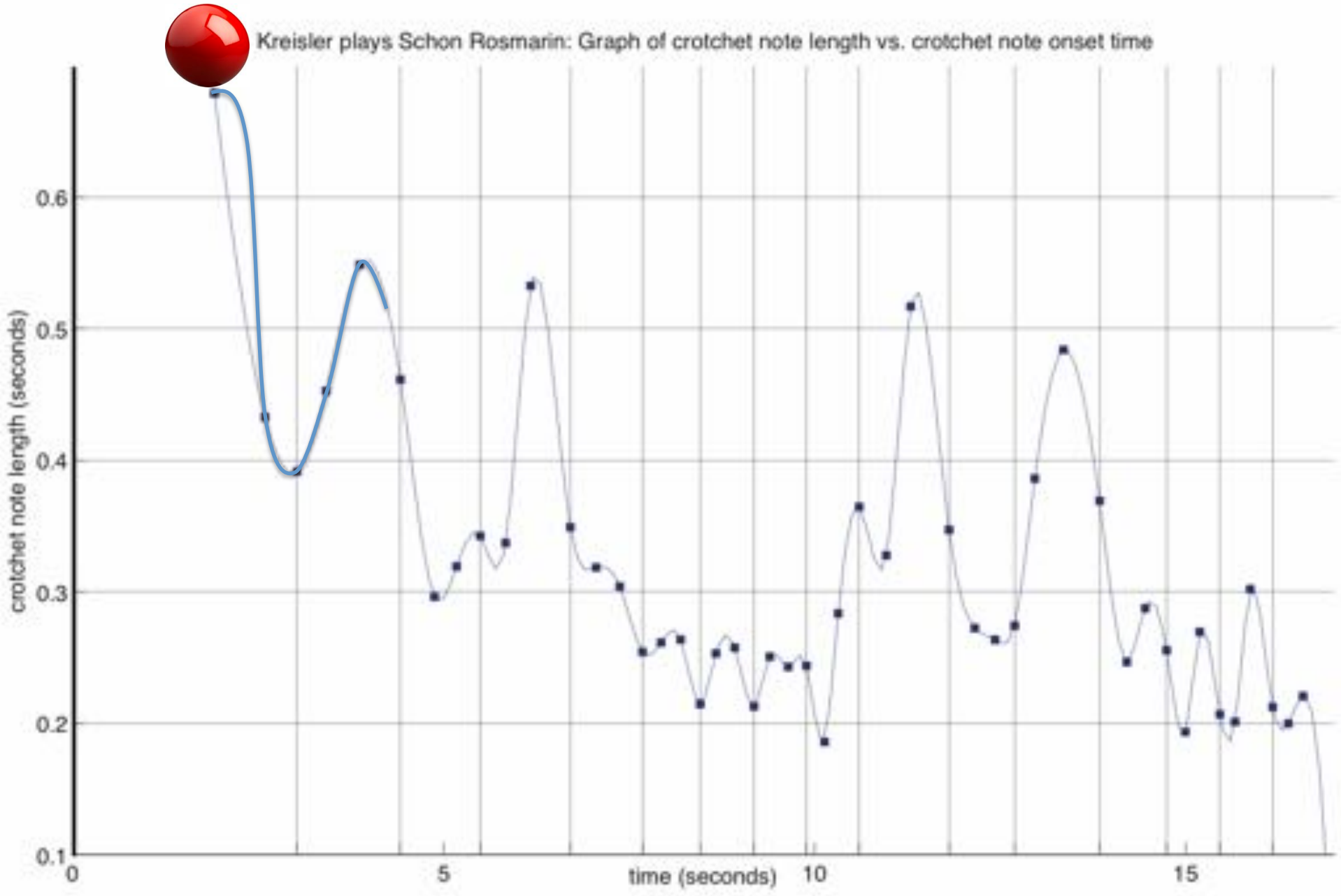
Fritz Kreisler

crotchet note length (seconds)

0
0.1
0.2
0.3
0.4
0.5
0.6

3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48



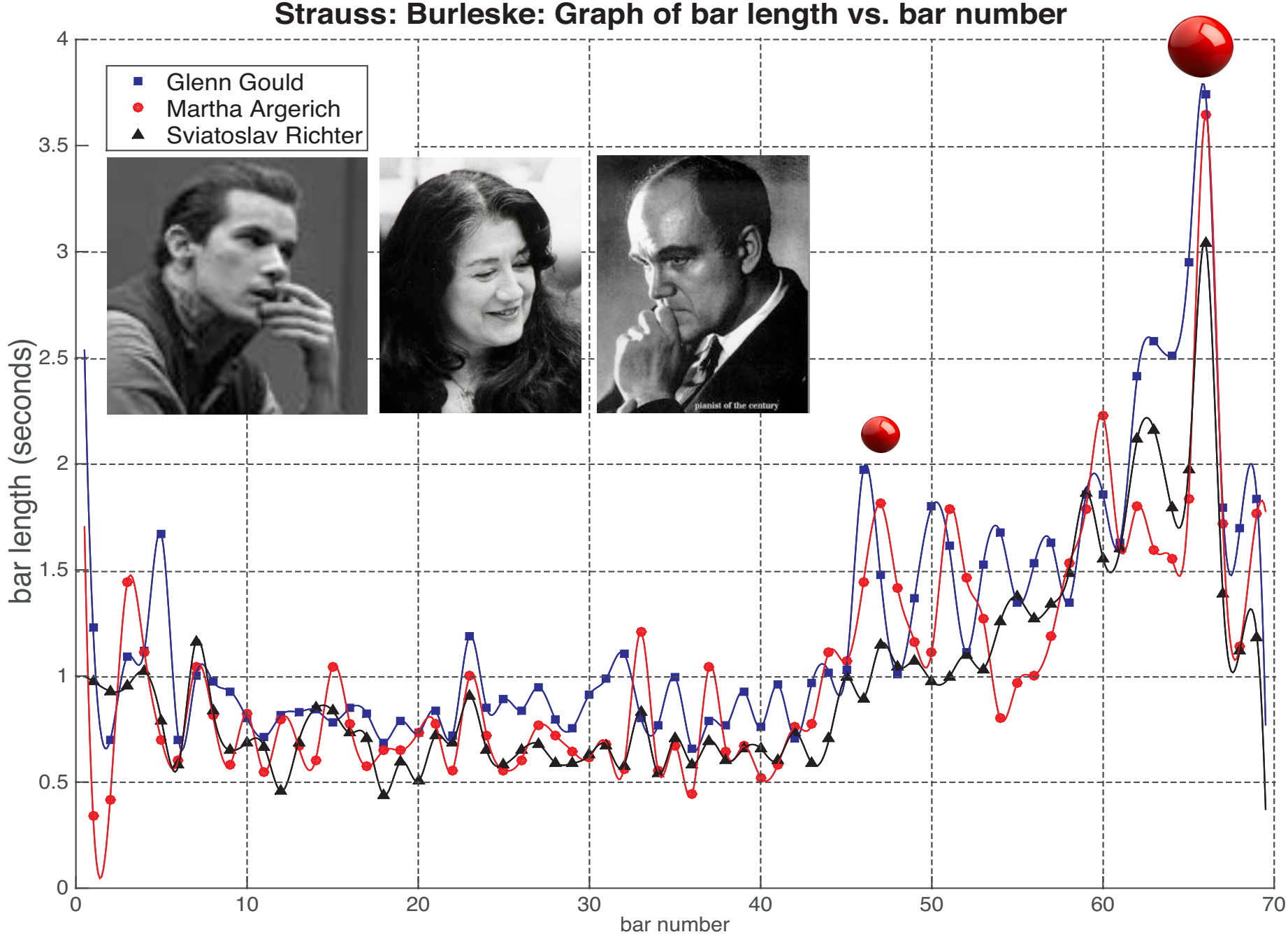

Kreisler plays Schon Rosmarin: Graph of crotchet note length vs. crotchet note onset time
crotchet note length (seconds)
0.6
0.5
0.4
0.3
0.2
0.1
0
5
time (seconds)
10
15

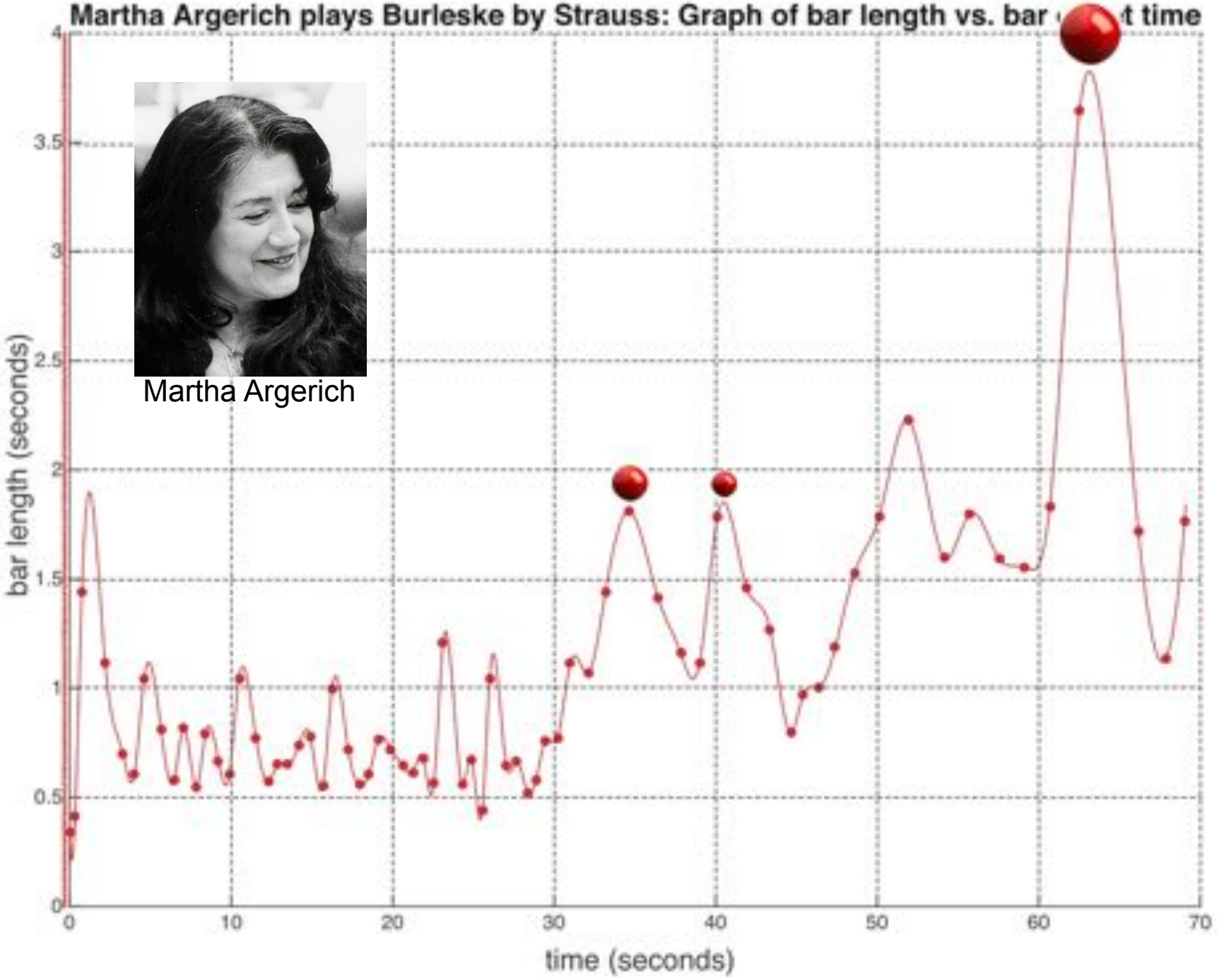

butchbellah.com

15:20

https://youtu.be/4q_zSvns0QY

Strauss: Burleske: Graph of bar length vs. bar number




Martha Argerich plays Burleske by Strauss: Graph of bar length vs. bar
t time
Martha Argerich
bar length (seconds)
time (seconds)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
10
20
30
40
50
60
70

Chew, E. (2016). Playing with the edge: Tipping points and the role of tonality. In Stephen McAdams, David Temperley, Alexander Rozin (eds.): Milestones in Music Cognition Special Issue, *Music Perception*, 33(3):344-366.

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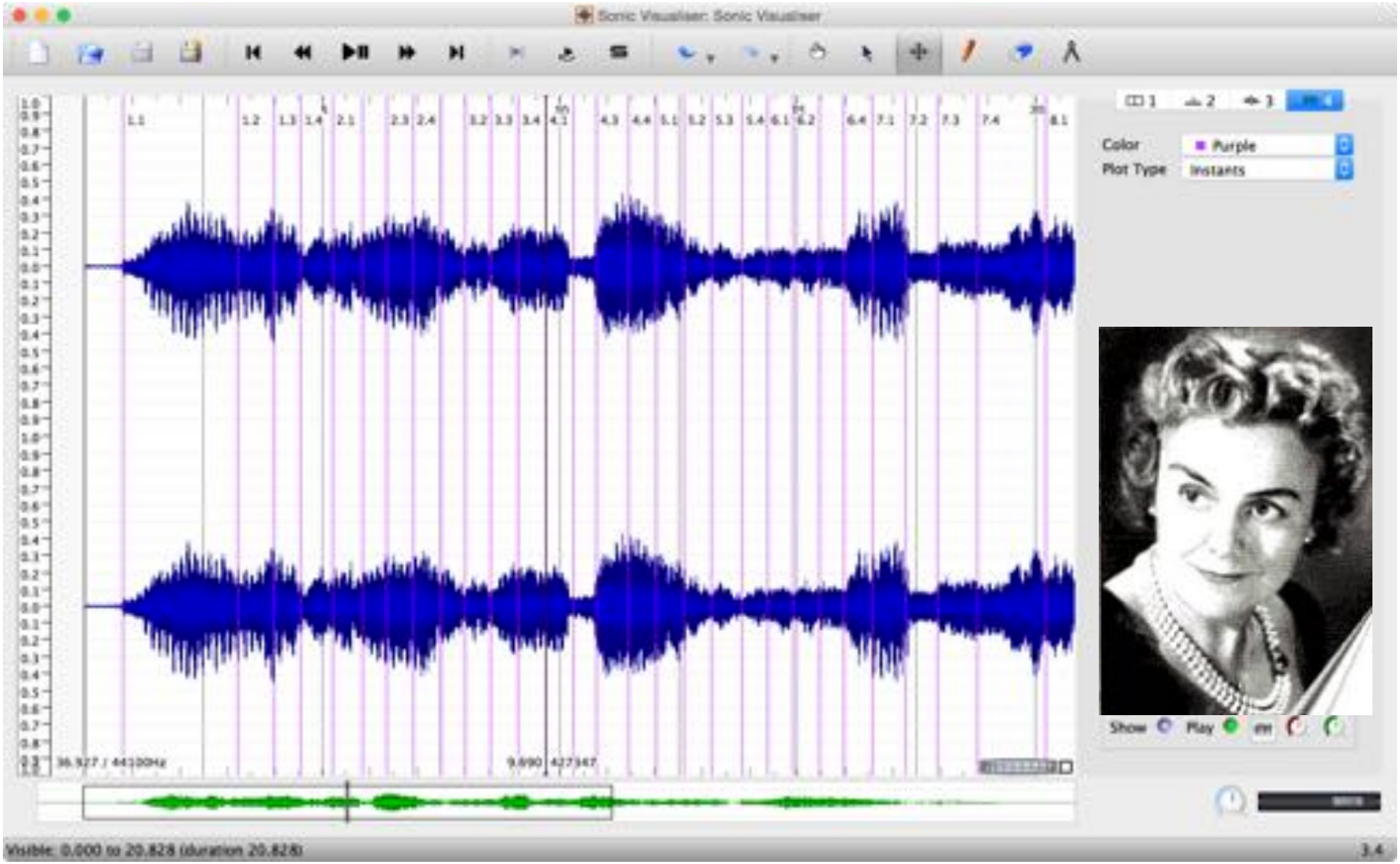
Creator: Chris Cannam et al.



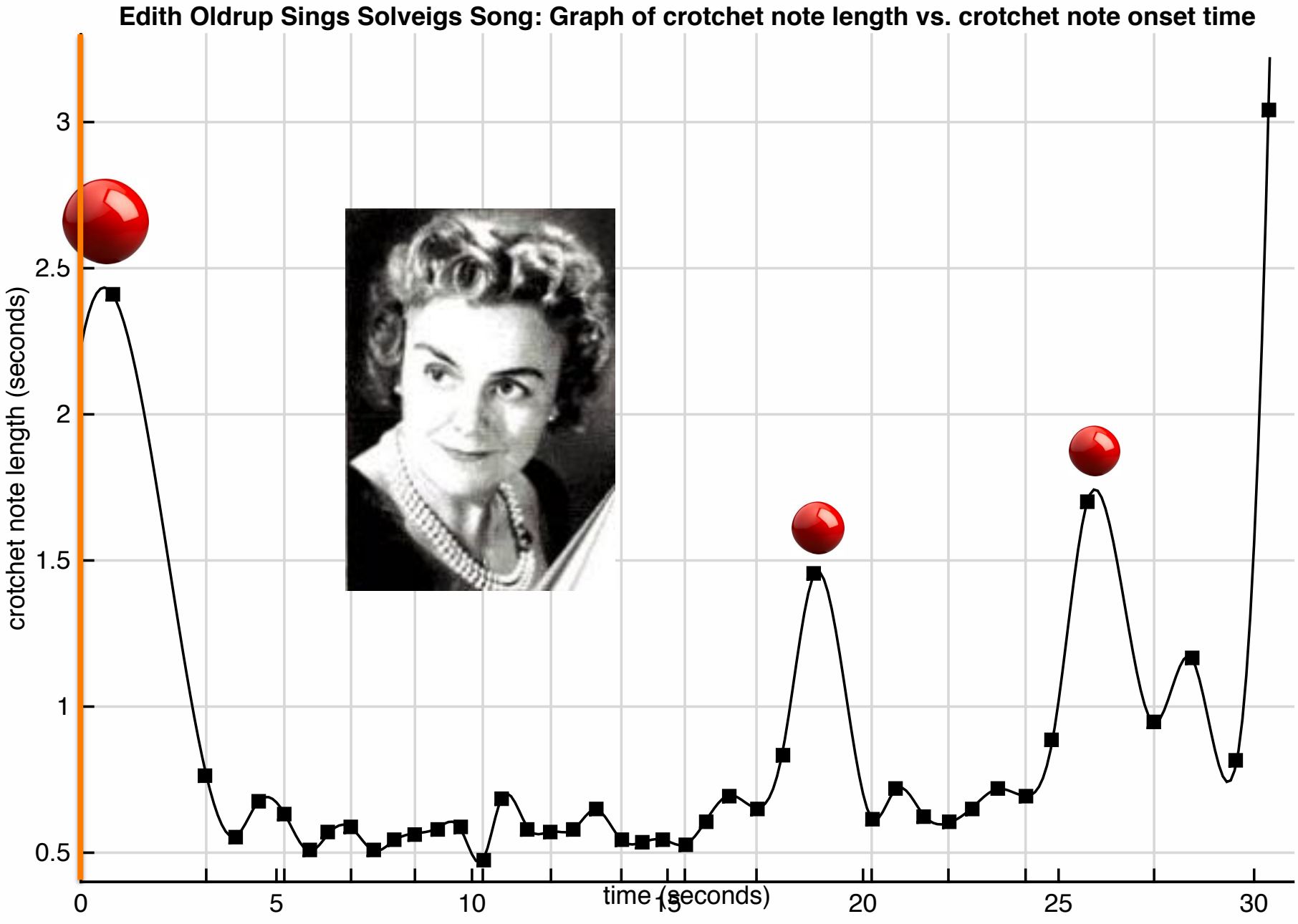
sonicvisualiser.org

Edith Oldrup Sings Solvejgs Song: Graph of crotchet note length vs. beat

crotchet note length (seconds)

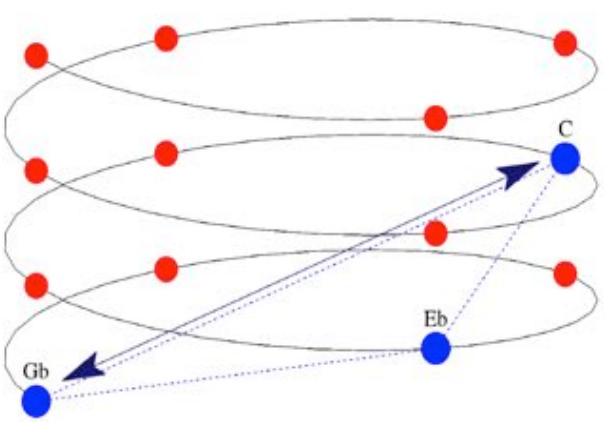
0
0.5
1
1.5
2
2.5
3

2 5 8 11 14 17 20 23 26 29 32 35 38 41

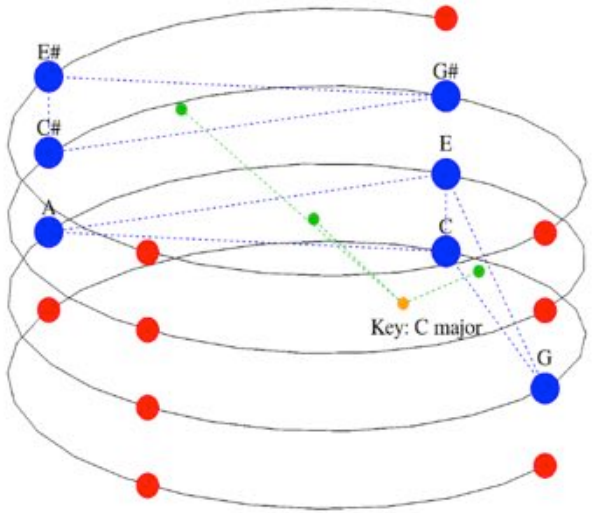

Edith Oldrup Sings Solveigs Song: Graph of crotchet note length vs. crotchet note onset time
crotchet note length (seconds)
3
2.5
2
1.5
1
0.5
0
5
10
15
20
25
30
time (seconds)

Tension

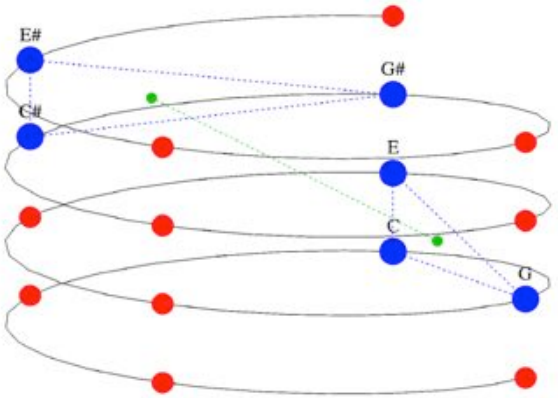
Modelling Tension



Cloud diameter



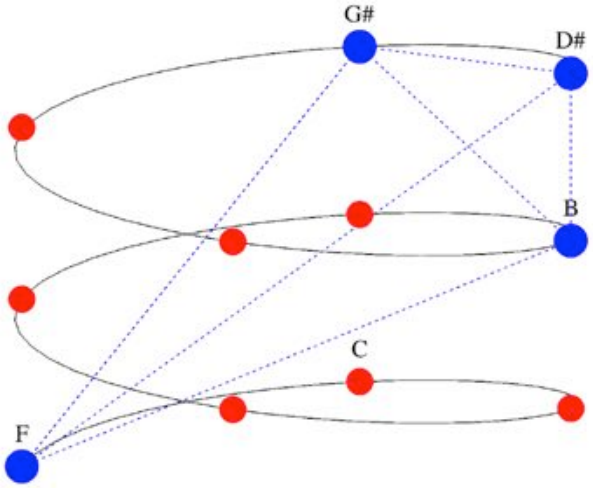
Tensile strain (distance to key)

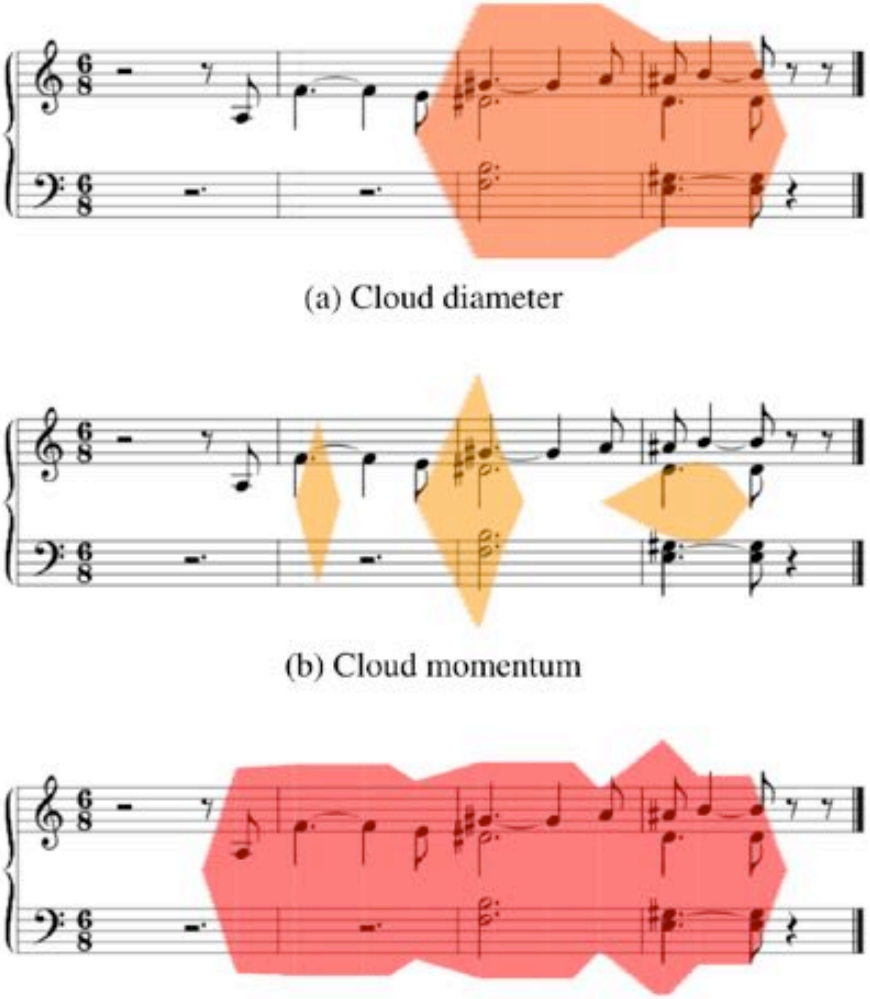


Cloud momentum

Herremans, D., E. Chew (2016). Tension Ribbons: Quantifying and visualising tonal tension. In Proceedings of the Second International Conference on Technologies for Music Notation and Representation (TENOR), Anglia Ruskin University, Cambridge, May 27-29, 2016.

Tension ribbons (Tristan chord)



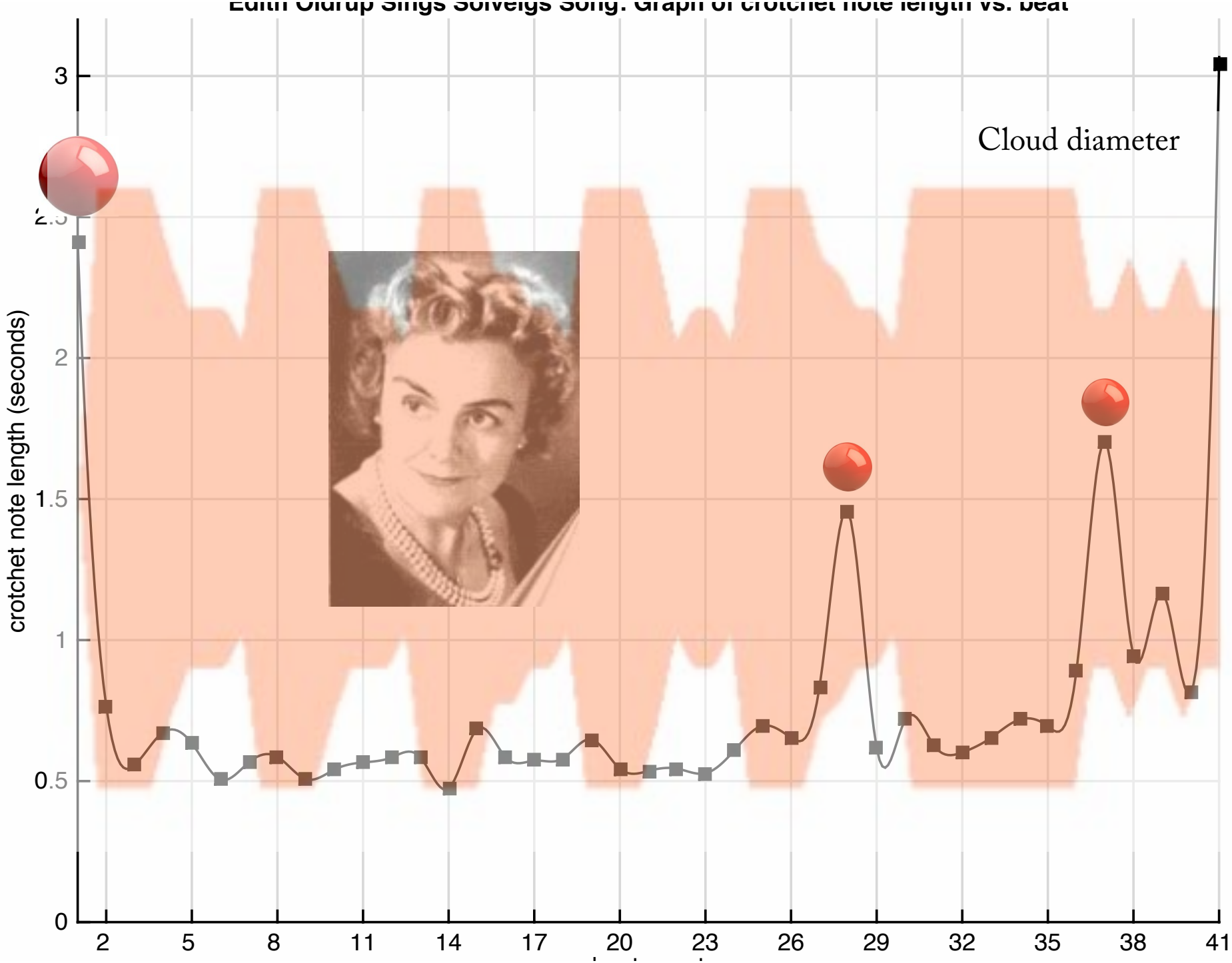


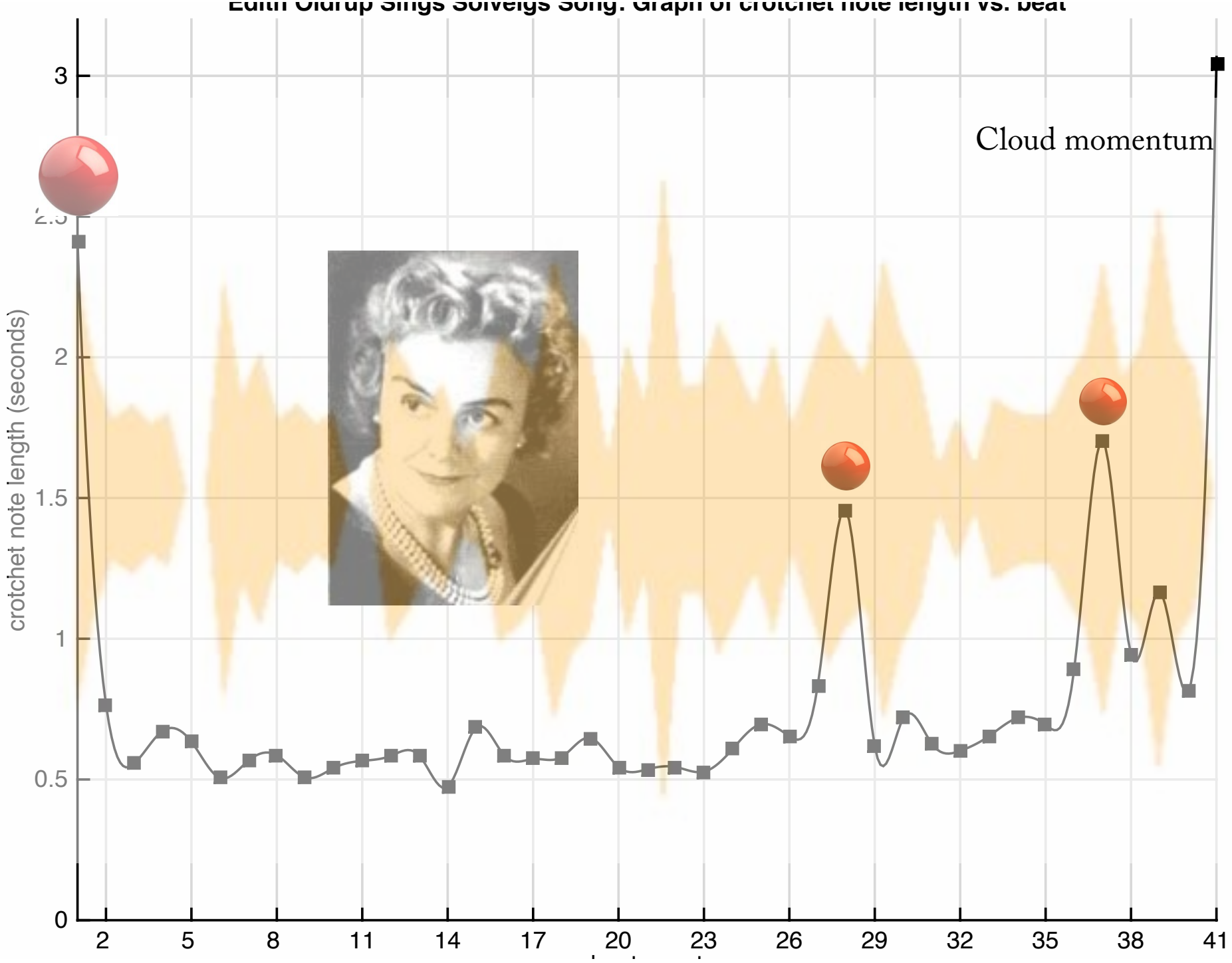
(a) Cloud diameter

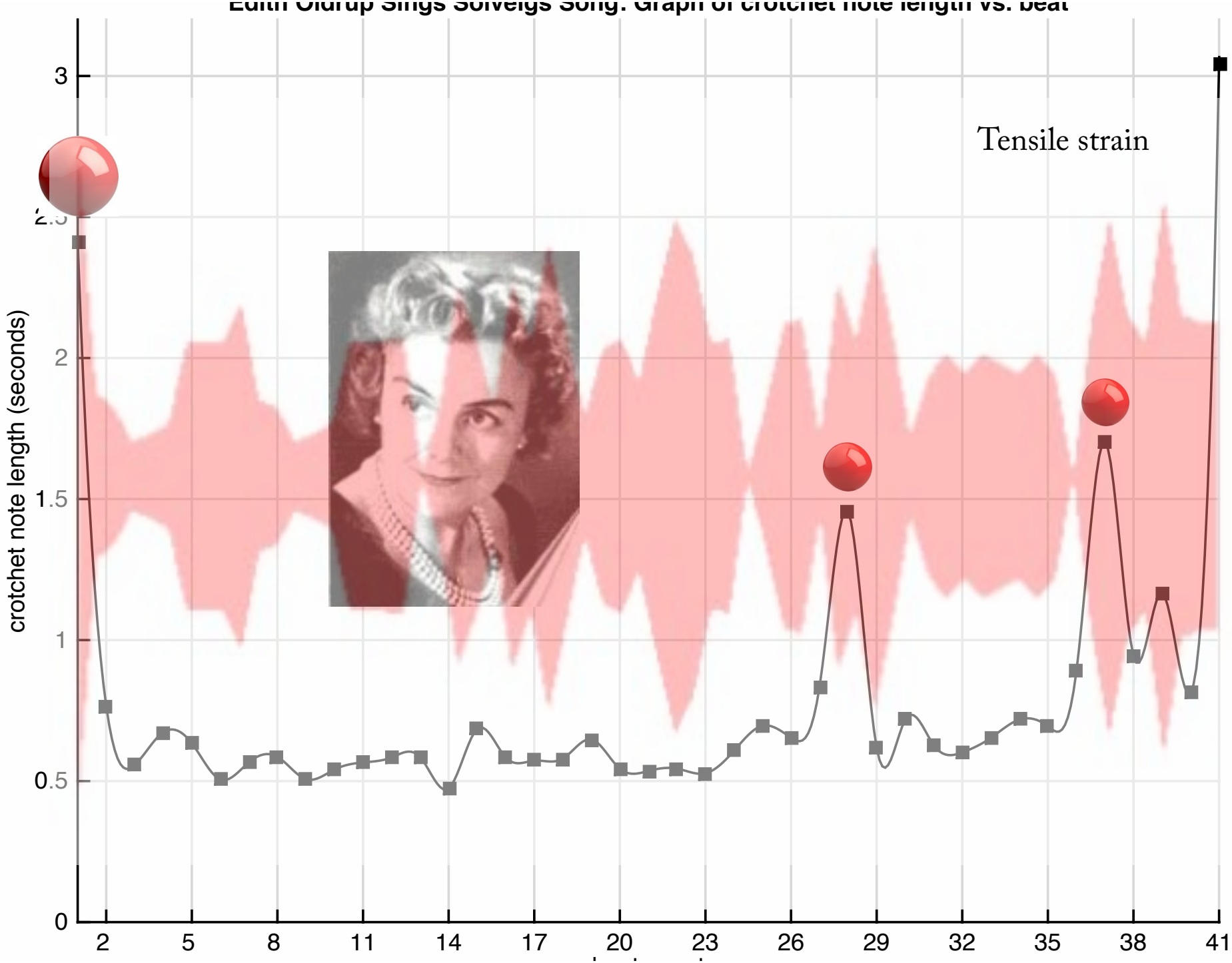
(b) Cloud momentum

(c) Tensile strain

Herremans, D., E. Chew (2016). Tension Ribbons: Quantifying and visualising tonal tension. In Proceedings of the Second International Conference on Technologies for Music Notation and Representation (TENOR), Anglia Ruskin University, Cambridge, May 27-29, 2016.

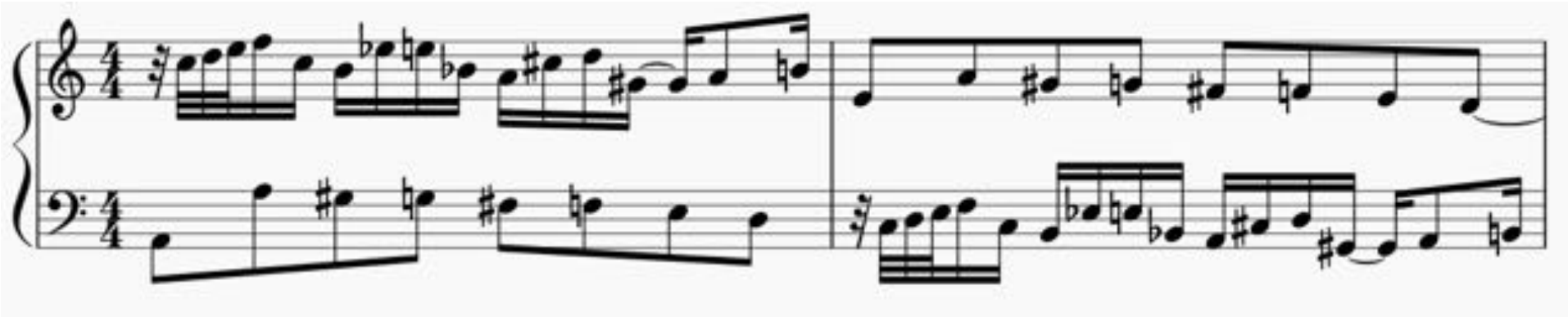

Edith Oldrup Sings Solvejgs Song: Graph of crotchet note length vs. beat
Cloud diameter
crotchet note length (seconds)
3
2.5
2
1.5
1
0.5
0
2
5
8
11
14
17
20
23
26
29
32
35
38
41

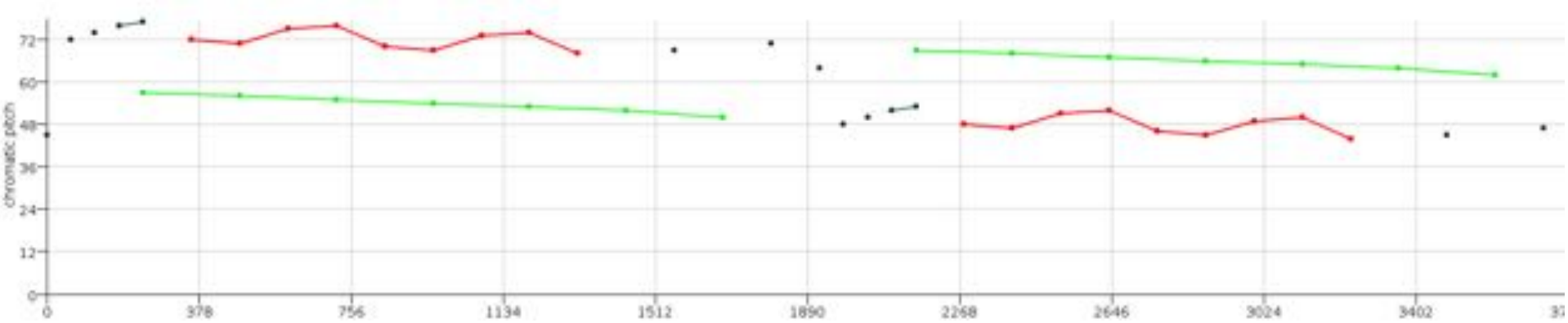

Edith Oldrup Sings Solvejgs Song: Graph of crotchet note length vs. beat
Cloud momentum
crotchet note length (seconds)
3
2.5
2
1.5
1
0.5
0
2
5
8
11
14
17
20
23
26
29
32
35
38
41


Edith Oldrup Sings Solvejgs Song: Graph of crotchet note length vs. beat
Tensile strain
crotchet note length (seconds)
3
2.5
2
1.5
1
0.5
0
2
5
8
11
14
17
20
23
26
29
32
35
38
41

Repeated Pattern Constraints

SIATECCompress / COSIATEC by David Meredith





COSIATEC output for for Bach WTC II Prelude XX

Repeated Pattern Constraints

SIATECCompress / COSIATEC by David Meredith

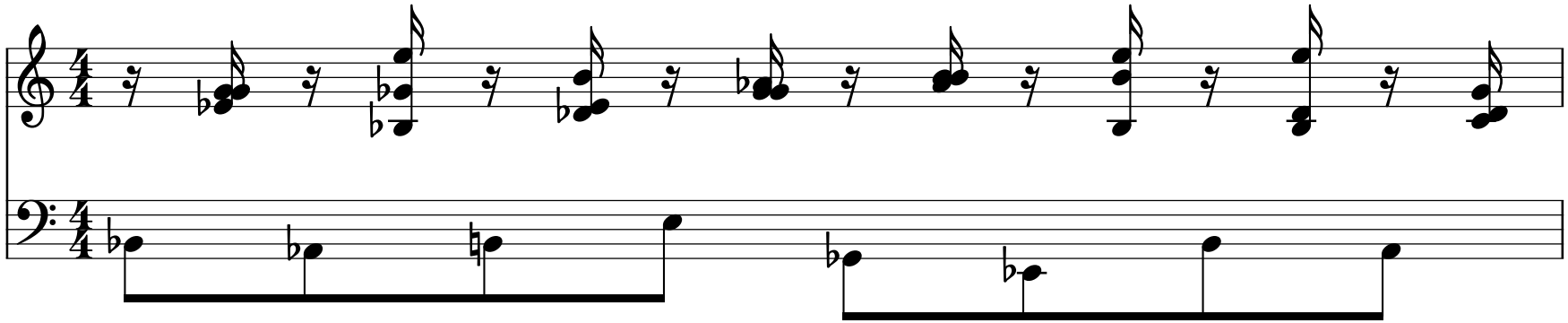
COSIATEC output for for PDQ Bach STC Prelude I

+ Variable Neighborhood Search

Herremans, D., E. Chew (2017). MorpheuS: generating structured music with constrained patterns and tension. *IEEE Transactions on Affective Computing*.

Prelude in C from the Short-tempered Clavier (start)

MorpheuS-PDQ Bach



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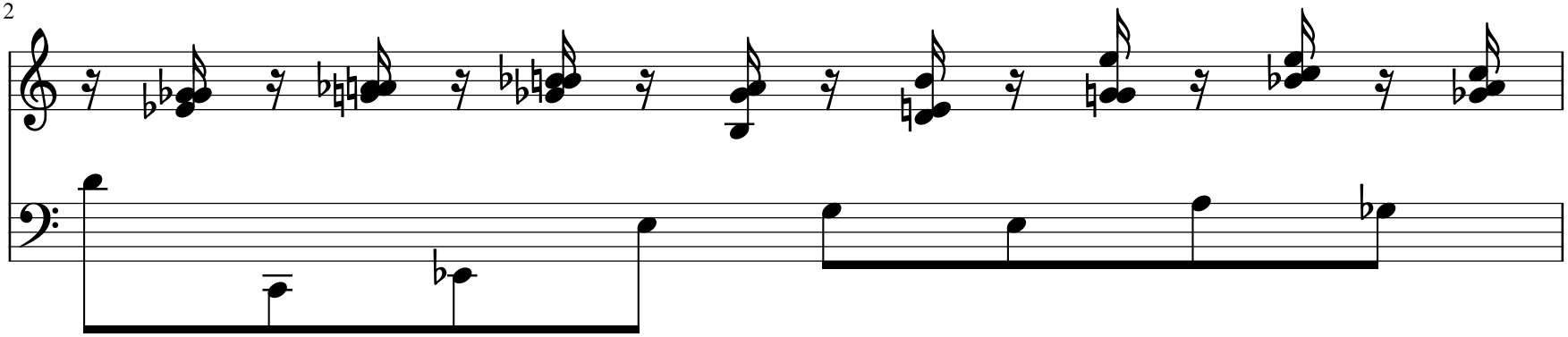
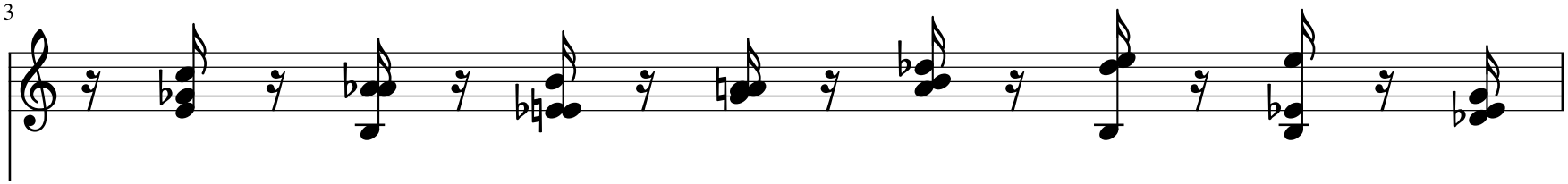
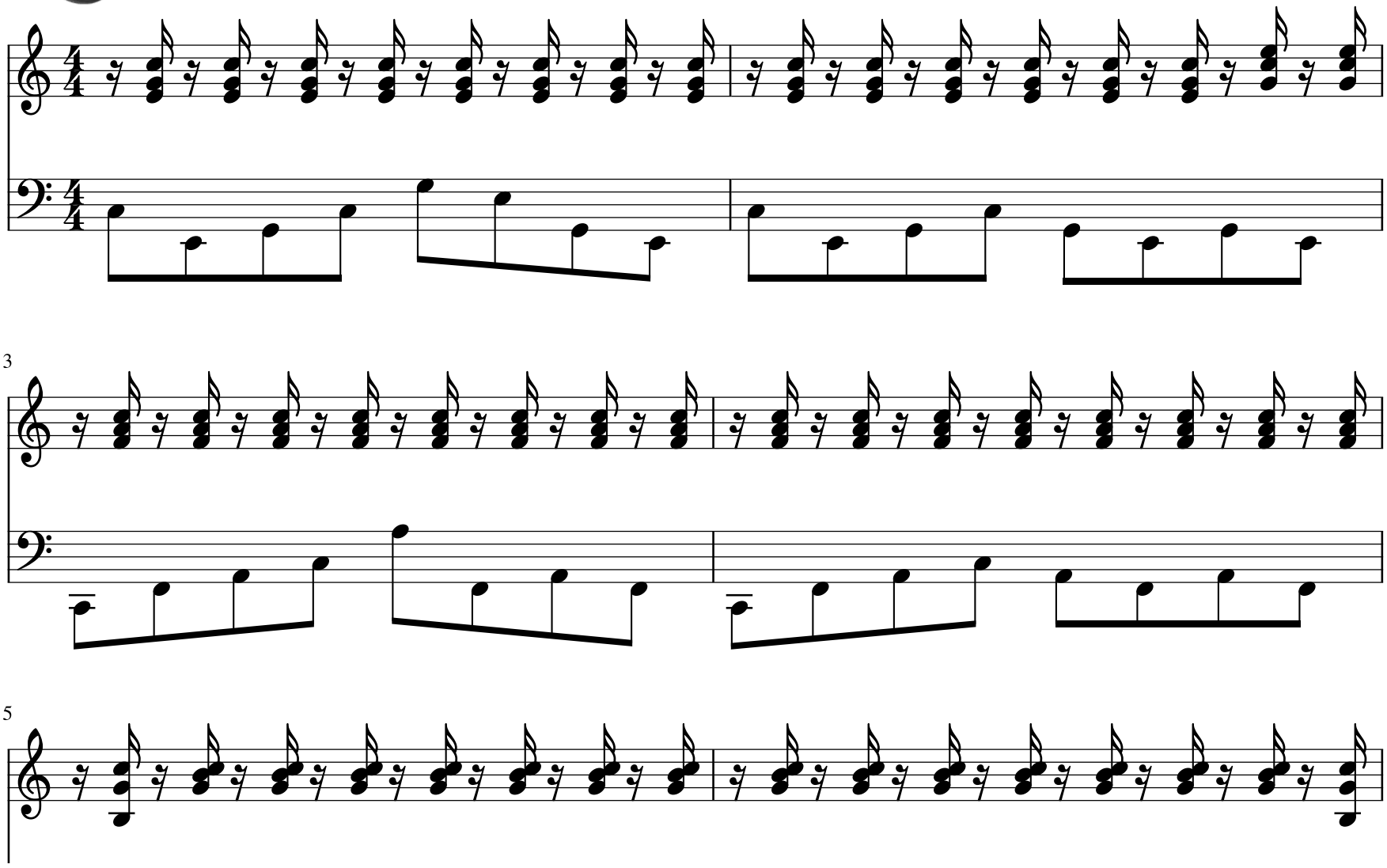


3



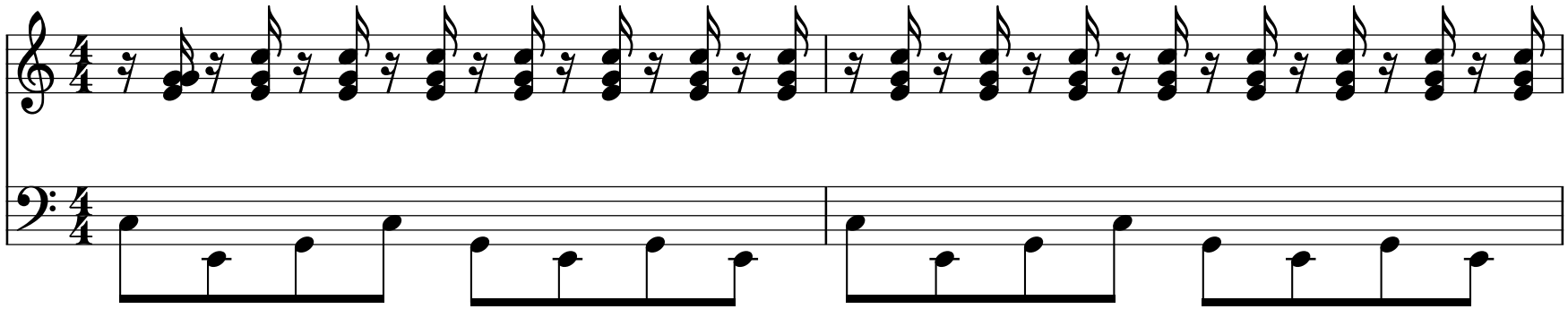
Prelude in C from the Short-tempered Clavier (iter 1)

MorpheuS-PDQ Bach

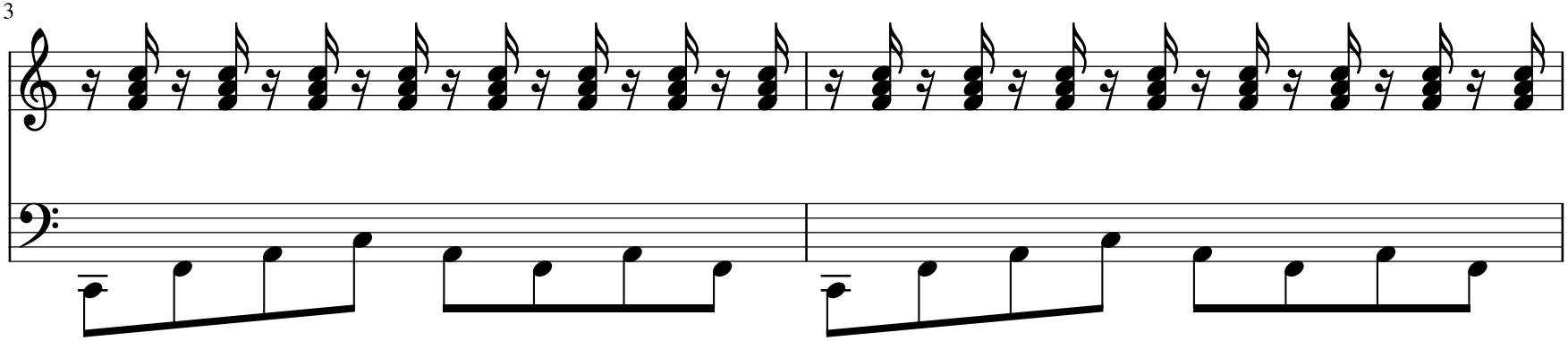


Prelude in C from the Short-tempered Clavier (iter 3)

MorpheuS-PDQ Bach



3



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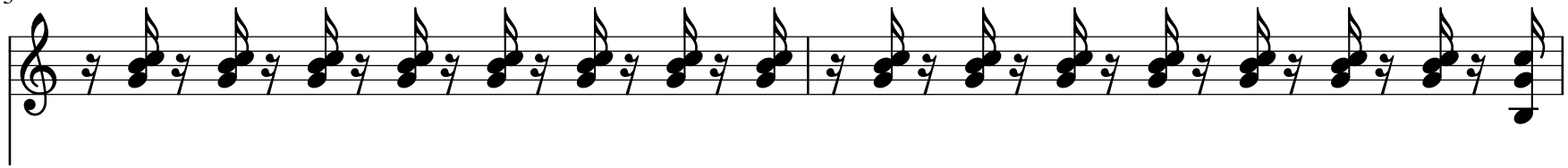
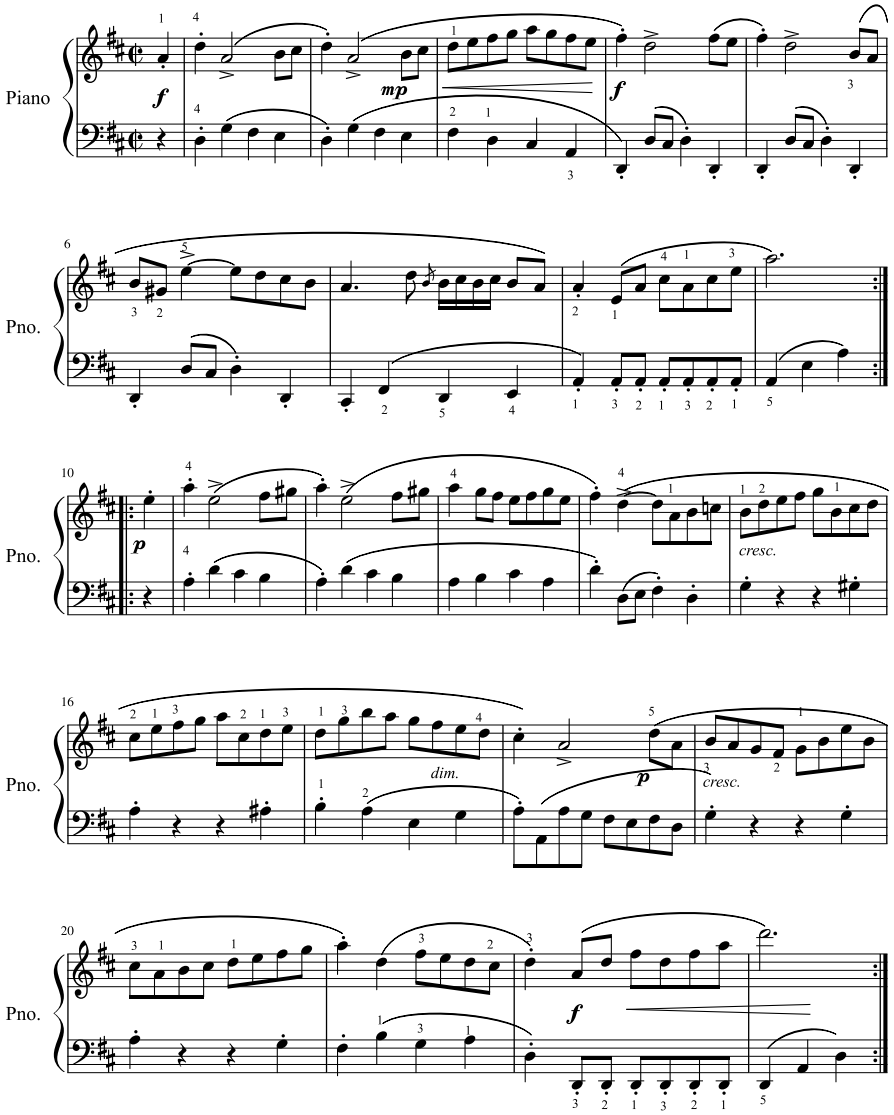


March in D Major (BWV Anh. 122)

from the Notebook for Anna Magdalena Bach

Johann Sebastian Bach

Animato

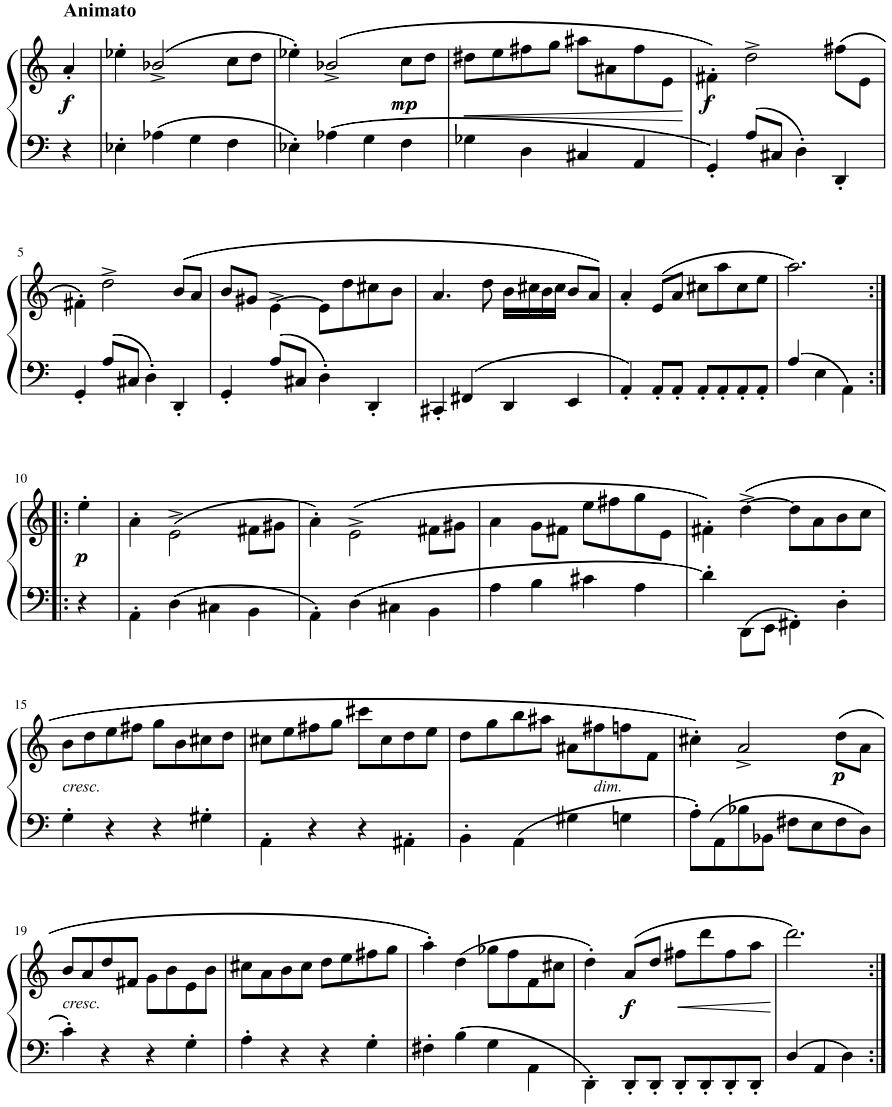


March in D Major (BWV Anh. 122)

from A Little Notebook for Anna Magdalena Bach

MorpheuS-Bach

Animato



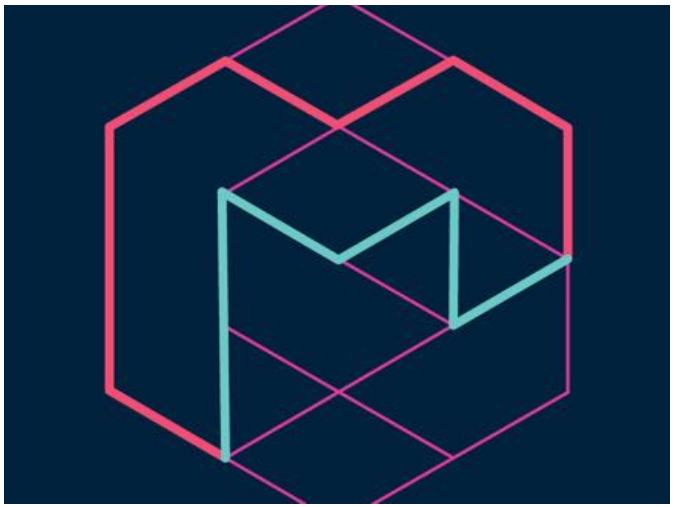
MorpheuS

Dorien Herremans and Elaine Chew
dorienherremans.com/MorpheuS

Music Generation

- Google Magenta Project
- Jukedeck
- MeloDrive

melodrive
adaptive music generation



Agenda

- A moving experience
  - Strong emotions: frisson, laughter, awe
- Expectation
  - Fulfillment: Reward
  - Violation: Surprise, laughter
- Tension, anticipation
  - Delayed resolution
  - Density of activity
- Prominence
  - Note-level variations
  - Vibrato and portamento
- Contrast
  - Section-level variations
  - Key change
- Time
  - Phrase-level variations
  - Tipping points
- Tension

THANK YOU

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Research Team – mupae.blogspot.com

Piano Blog – elainechew-piano.blogspot.com

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University of London

centre for digital music