International Conference on Music Information Retrieval 2005
Tutorial 1: Music Background (Part II)
Goldsmiths College, University of London

1430h-1530h, Sunday, September 11, 2005
Ben Pimlott Building

Looking Beyond the Notes: An Engineering Approach to the Study of Musical Performance

Elaine Chew
Assistant Professor, Viterbi Early Career Chair
Epstein Department of Industrial and Systems Engineering
Research Area Director, Integrated Media Systems Center

USC

USC Viterbi School of Engineering

USC Viterbi School of Engineering

AGENDA

- **Introduction**
- **From score to performance**
  - Example: structure-expression link
  - Interpreting Child's *Epilogue*
- **Making performances**
  - ESP: the expression synthesis project
- **Collaborative performance**
  - DIP: distributed immersive performance
- **Related presentations at ISMIR**

USC Viterbi School of Engineering

JEANNE BAMBERGER

… symbol systems associated with all disciplines are necessarily partial and they are so in two senses: they are incomplete and they are also"partial-to" certain features while minimizing the importance of others. At the same time, by giving privileged status to these symbol systems, their referents, and their modes of description (sometimes thought to be explanations), users run the risk of coming to believe that the features and relations to which the symbols refer are the only "things," the only objects that exist in the domain. At the most extreme, this implicit ontological commitment has the potential of becoming a kind of ***ontological imperialism***.

(April 17, 2005)

USC Viterbi School of Engineering

PALMER on music performance (1997)

Western tonal music has developed a notation that represents pitch and duration information fairly explicitly but intensity and tone quality only approximately. Other relationships, such as ***group boundaries***, ***metrical levels*** *higher than the measure*, and ***patterns of motion, tension, and relaxation*** are unspecified or only implicitly specified in notation. Thus ambiguities in musical notation allow a performer considerable freedom in deciding how to interpret the music's content.

USC Viterbi School of Engineering

PALMER on music performance (1997)

- Conceptual interpretation
  - *to highlight structural content*
    - phrase, melody, metric grouping
  - *to highlight emotional content*
- Retrieval from memory of musical structures
- Transformation into appropriate motor actions
- Perceptual consequences
  - *successful communication of interpretation*
  - *resolution of structural ambiguities*
    - phrases, level of embedding
  - *concordance with listeners' expectations*
    - melodic expectancy, tension/relaxation

USC Viterbi School of Engineering

PALMER on music performance (1997)

- **Conceptual interpretation**
  - ***to highlight structural content***
    - phrase, melody, metric grouping
  - *to highlight emotional content*
- Retrieval from memory of musical structures
- Transformation into appropriate motor actions
- **Perceptual consequences**
  - *successful communication of interpretation*
  - ***resolution of structural ambiguities***
    - phrases, level of embedding
  - ***concordance with listeners' expectations***
    - melodic expectancy, tension/relaxation

USC Viterbi School of Engineering

EXPRESSIVE TOOLS

PROPERTY	FIRST ORDER DIFFERENCE
TEMPO	TEMPO CHANGE (acceleration/deceleration)
LOUDNESS	DYNAMIC RANGE

Cambouropoulos, Dixon, Goebl, Widmer (2001)

Human Preference for tempo smoothness

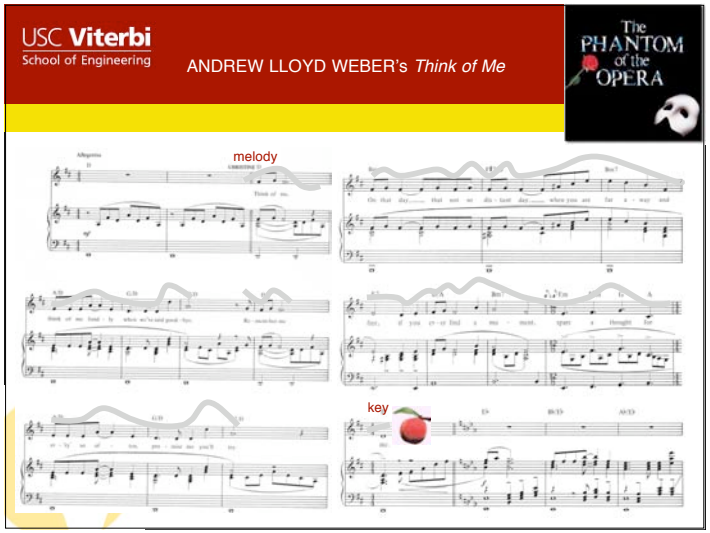
USC Viterbi School of Engineering

AGENDA

- **Introduction**
- **From score to performance**
  - Example: structure-expression link
  - Interpreting Child's *Epilogue*
- **Making performances**
  - ESP: the expression synthesis project
- **Collaborative performance**
  - DIP: distributed immersive performance
- **Related presentations at ISMIR**

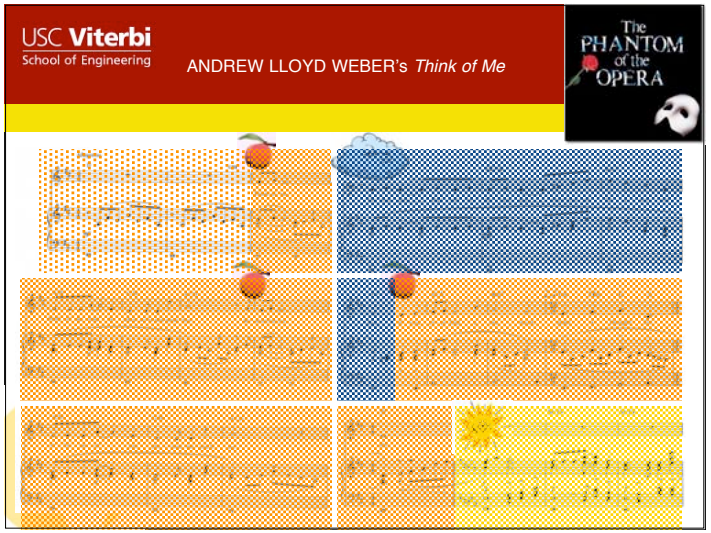
USC Viterbi School of Engineering

ANDREW LLOYD WEBER's *Think of Me*



USC Viterbi School of Engineering

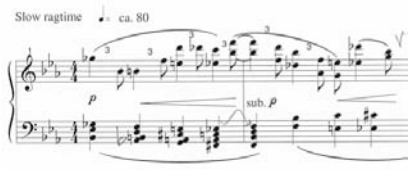
ANDREW LLOYD WEBER's *Think of Me*



USC Viterbi School of Engineering

PETER CHILD's *Epilogue* from DOUBLES (1999)

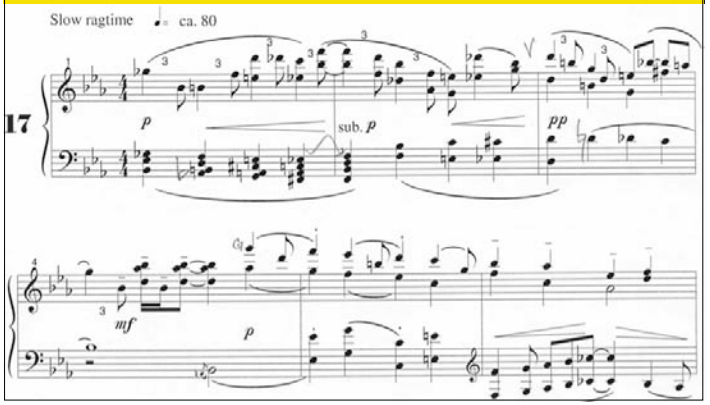
Photo: Donna Coveney



- *http://web.mit.edu/child/www*
- Professor of Music and MacVicar Faculty Fellow at MIT
- Chair of department of Music and Theater Arts from 1996 to 1999.

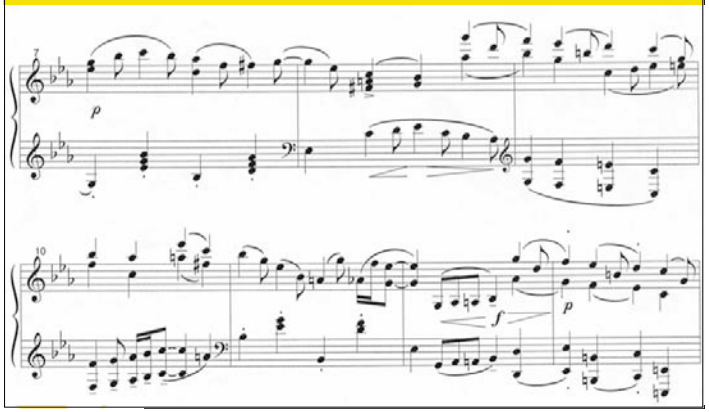
USC Viterbi School of Engineering

PETER CHILD's *Epilogue* from DOUBLES (1999)



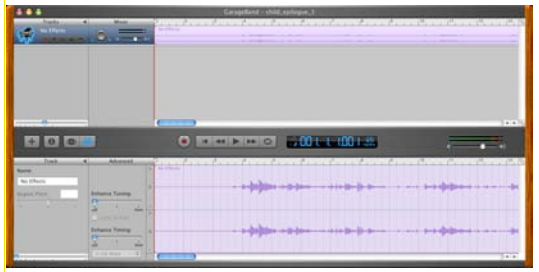
USC Viterbi School of Engineering

PETER CHILD's *Epilogue* from DOUBLES (1999)



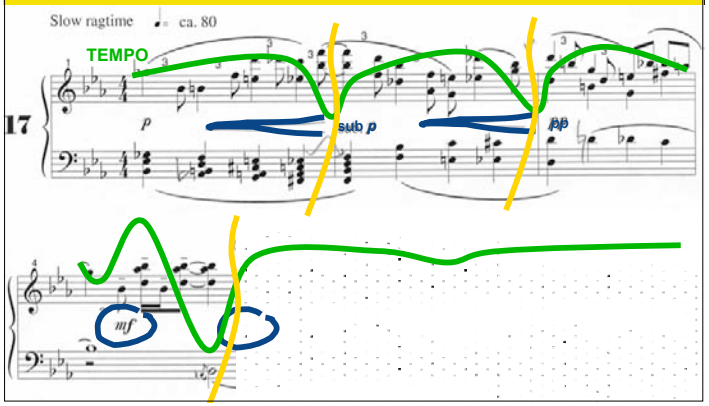
USC Viterbi School of Engineering

PETER CHILD's *Epilogue* from DOUBLES (1999)



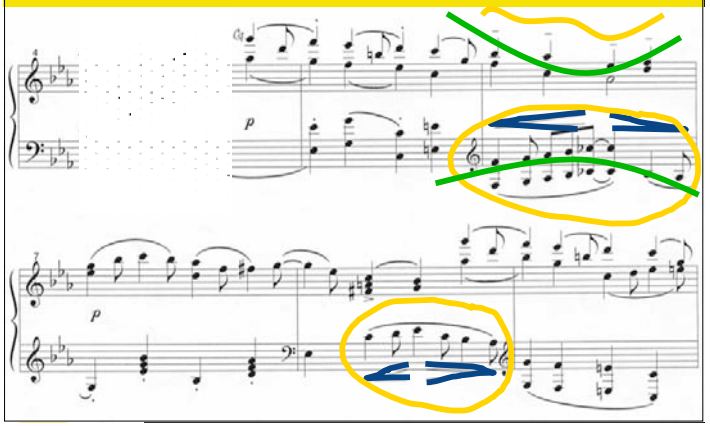
USC Viterbi School of Engineering

PETER CHILD's *Epilogue* from DOUBLES (1999)



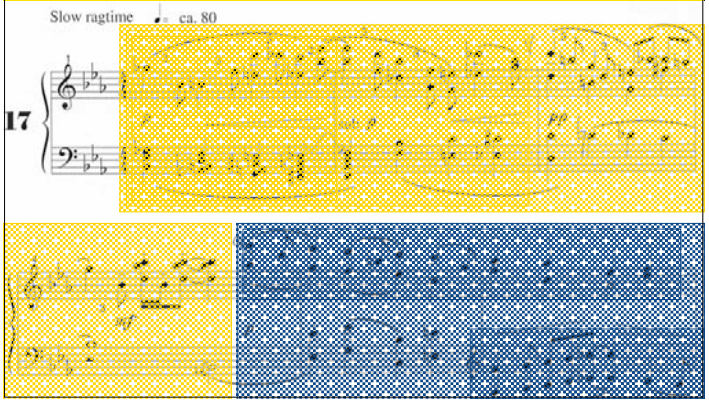
USC Viterbi School of Engineering

PETER CHILD's *Epilogue* from DOUBLES (1999)



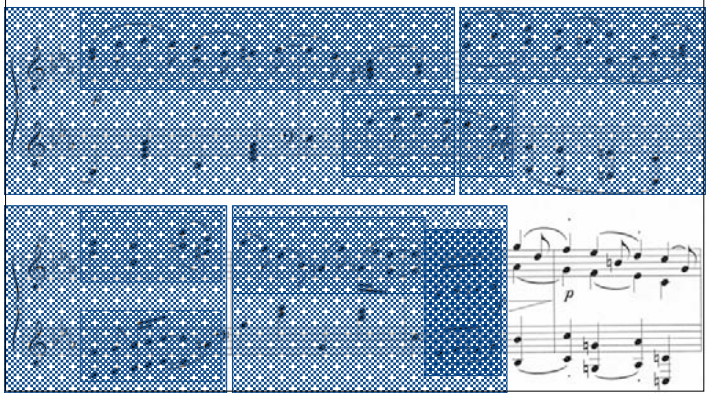
USC Viterbi School of Engineering

PETER CHILD's *Epilogue* from DOUBLES (1999)



USC Viterbi School of Engineering

PETER CHILD's *Epilogue* from DOUBLES (1999)



USC Viterbi School of Engineering

AGENDA

- **Introduction**
- **From score to performance**
  - Example: structure-expression link
  - Interpreting Child's *Epilogue*
- **Making performances**
  - ESP: the expression synthesis project
- **Collaborative performance**
  - DIP: distributed immersive performance
- **Related presentations at ISMIR**

USC Viterbi School of Engineering

ESP - the EXPRESSION SYNTHESIS PROJECT

ESP TEAM:

Elaine Chew, Alex François, Jie Liu and Aaron Yang

USC Viterbi School of Engineering

ESP - the EXPRESSION SYNTHESIS PROJECT

ADVANTAGES

Compelling metaphor
Common interface
Tempo smoothness

www.geocities.com/TelevisionCity

www.geocities.com/Broadway/Stage/7840

USC Viterbi School of Engineering

ESP - the PEDALS

$$a = \lambda_1 F - \lambda_2 v^2 + K_1(\delta,\omega),$$

where λ_1 and λ_2 are constants, and K_1 is a function of the angle of the wheel, δ, and of the angular velocity, ω. Simulated

$$a = -\eta_1 \delta - \eta_2 v^2 + K_2(F,\omega),$$

where η_1 and η_2 are constants, and K_2 is a function of the forward force, F, and of the angular velocity, ω.

Tempo: $T_t = T_{t-1} + a\,dt$

Distance: $D_t = D_{t-1} + T_t\,dt$

Volume: $V_t = V_0 + a\,\mu$

USC Viterbi School of Engineering

ESP - the DISPLAY and WHEEL

Bends in the road indicate:

- structural boundaries (e.g. phrases)
- distant harmonic changes
- score-based instructions to slow down

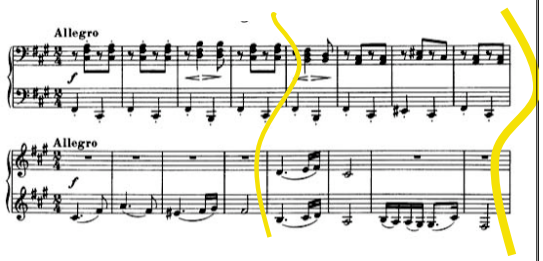
Idea: bends suggest more care in traversing that part of the road.

USC Viterbi School of Engineering

BRAHMS' HUNGARIAN DANCE No.5

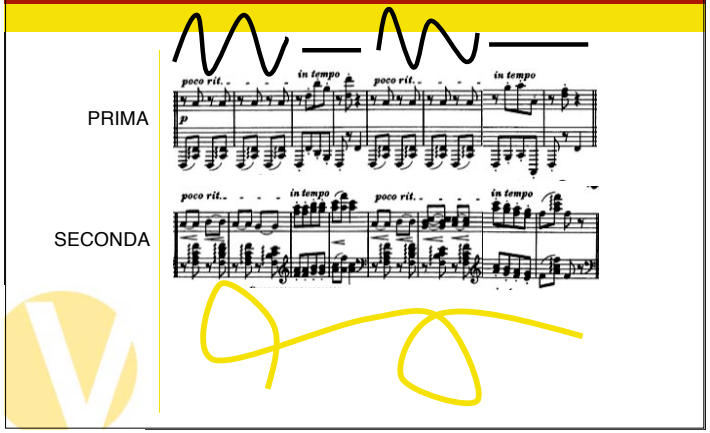
PRIMA

SECONDA



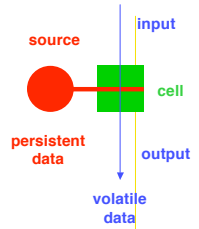
USC Viterbi School of Engineering

BRAHMS' HUNGARIAN DANCE No.5



USC Viterbi School of Engineering

FRANÇOIS' Software Architecture for Immersipresence



Streams consisting of *volatile data*

Cells that serve as *processing units* (asynchronous parallel model)

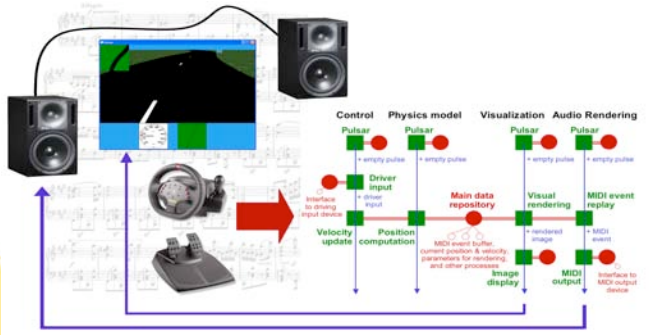
Sources that serve as repositories of *persistent data*

Pulses that *synchronize structure* (time stamps, duration)
Active: volatile, flow down stream connections
Passive: persistent (dynamic), held in sources

(see François 2004)

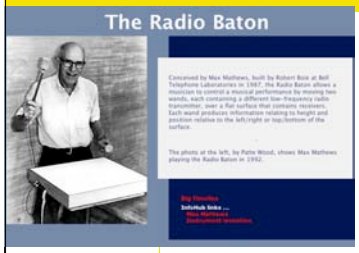
USC Viterbi School of Engineering

ESP SYSTEM DIAGRAM



USC Viterbi School of Engineering

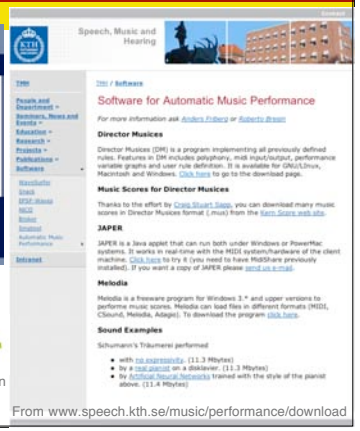
RELATED WORK



From emfinstitute.emf.org/exhibits/radiobaton.html

Renc n

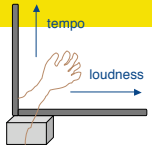
shouchan.ei.tuat.ac.jp/~rencon



From www.speech.kth.se/music/performance/download

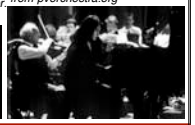
USC Viterbi School of Engineering

COMPARISON OF REAL-TIME SYSTEMS



From conductor cool.ne.jp

from pvorchestra.org



	ESP (2005)	Air Worm (2005)	Conducting	Automated accomp.
Interface	Wheel and pedal	Theremin	Gestures	Solo instrument
Mental model	Driving metaphor	Langner's Tempo-Loudness space	Conducting	Ensemble
Input	Deadpan MIDI	Audio recording	MIDI or audio	Audio (music minus one)
Parameters controlled	Tempo, dynamics (linked to accel), and articulation	Tempo, loudness	Tempo, dynamics (varies)	Tempo
Users	Novice/experts	Novice/experts	Experts	Experts

USC Viterbi School of Engineering

ESP VIDEO AND EXAMPLES

SOME THINGS ESP CANNOT DO (yet)

Control timbre of sound, create agogic accents

Provide independent control of individual voices

USC Viterbi School of Engineering

AGENDA

- **Introduction**
- **From score to performance**
  - Example: structure-expression link
  - Interpreting Child's *Epilogue*
- **Making performances**
  - ESP: the expression synthesis project
- **Collaborative performance**
  - DIP: distributed immersive performance
- **Related presentations at ISMIR**

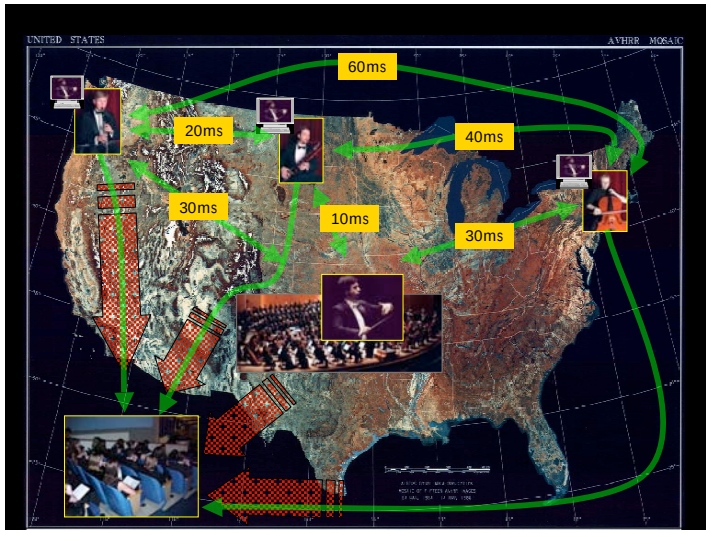
USC Viterbi School of Engineering

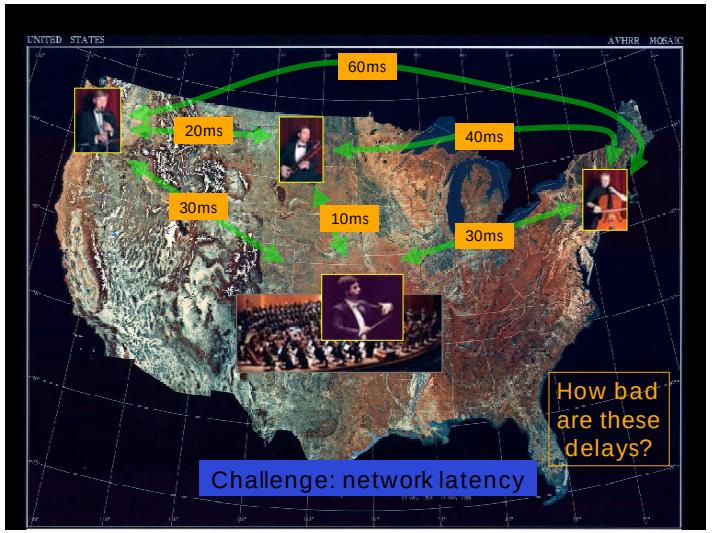
DISTRIBUTED IMMERSIVE PERFORMANCE

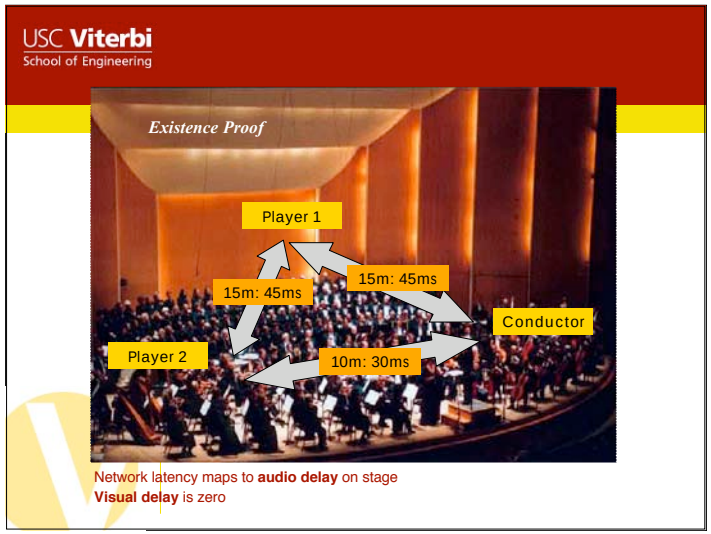
The **Distributed Immersive Performance** (DIP) project explores one of the most challenging goals of networked media technology: creating a seamless environment for **remote and synchronous musical collaboration**.

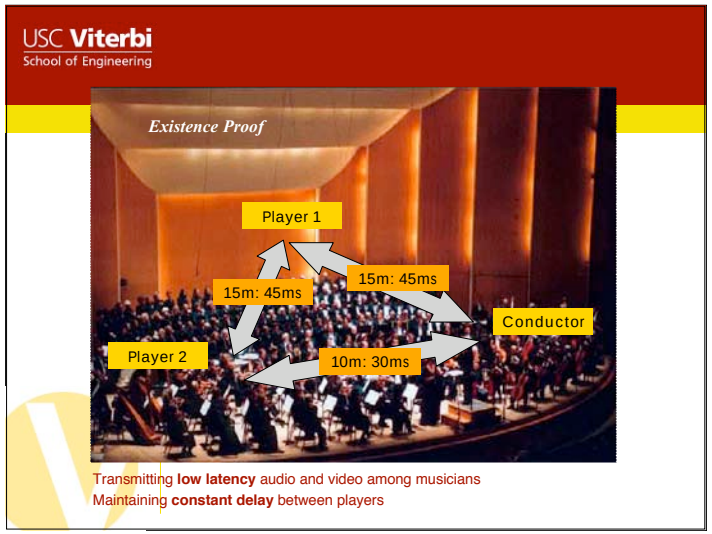
Elaine Chew, Alexander A. Sawchuk, Roger Zimmermann,
Chris Kyriakakis, Christos Papadopoulos,
Alexandre François, Anja Volk,
Vely Stoyanova, Ilya Tosheff,

Adapted from presentation given at the
National Association of Schools of Music (NASM) Meeting
in San Diego, CA, November 2004.


UNITED STATES
AVHRR MOSAIC
60ms
20ms
40ms
30ms
10ms
30ms


UNITED STATES
AVHRR MOSAIC
60ms
20ms
40ms
30ms
10ms
30ms
How bad are these delays?
Challenge: network latency


USC Viterbi
School of Engineering
Existence Proof
Player 1
15m: 45ms
15m: 45ms
Conductor
Player 2
10m: 30ms
Network latency maps to audio delay on stage
Visual delay is zero


USC Viterbi
School of Engineering
Existence Proof
Player 1
15m: 45ms
15m: 45ms
Conductor
Player 2
10m: 30ms
Transmitting low latency audio and video among musicians
Maintaining constant delay between players

USC Viterbi School of Engineering

RELATED WORK

1993 - USC Information Sciences Institute (ISI): distributed trio

1998 - "Mélange à trois" (audio only): Warsaw, Helsinki, Oslo

2002 - CCRMA's Network Jam (a/v unsynch): Stanford, McGill

2002 (Dec) - USC IMSC Distributed Duet (audio only): PHE, EEB

2003 (Jun) - USC IMSC Duet w Audience (a/v unsynch): PHE, RMH

2003 - UC Santa Barbara, Santa Barbara College

2004 (Mar) - USC IMSC DIP Experiment Set A & B

2004 (Jun) - CCRMA (audio only): CA, Sweden

2004 (Jul) - USC IMSC DIP Experiment Set C & D

2004 (Aug) - ICHIM Network Concert: Berlin, Paris

2005 (May) - NIME Network Concert: Vancouver, Troy, Marseilles

2002

Jun — Remote Media Immersion (RMI) Initial Demonstration
Oct — Internet2 Meeting: Large Room RMI Demonstration
Dec — **DIP v.0: Distributed Duet** (audio only)

2003

Jan — Recording from Streams
Jan — **Remote Master Class with New World Symphony**
Jun — **DIP v.1: Duet with Audience** (audio/video unsynch)

2004

Jan — Two-Way Live HD Streaming LA, Hawaii, Miami Experiments
Feb-Apr — **DIP v.2: Two-Way Baseline User Studies**
May — **A:** first time players perform under delayed conditions
B: player 1 and player 2 swap parts (symmetry test)
Jun — **C:** players practice to compensate for delay
D: players perform with both partner and self delayed
Sep — One-Way Live HD Streaming on Internet2: Austin, Texas

USC Viterbi School of Engineering

DIP v.0 - DISTRIBUTED DUET (2002)

Elaine Chew
on keyboard
in **Powell Hall**
with 1-channel
audio playback

Eran Egozy
clarinetist in trio

Wilson Hsieh
and viola in the
Electrical Engineering Bldg
with 10.2-channel
Immersive audio

TECHNOLOGY:
10.2-channel immersive audio technology by Kyriakakis & Holman
Low-latency multichannel audio streaming software by Papadopoulos & Sinha
Actual delay controlled using Protools console

EXPERIMENT
Varying audio delay: 0ms to >300ms
Pieces: Hindemith's *Sonata No.4* and Piazzolla's *Le Grand Tango*

USC Viterbi School of Engineering

DIP v.0 - DISTRIBUTED DUET (2002)

Elaine Chew
on keyboard
in **Powell Hall**
with 1-channel
audio playback

Eran Egozy
clarinetist in trio

Wilson Hsieh
and viola in the
Electrical Engineering Bldg
with 10.2-channel
Immersive audio

WHAT WE LEARNED:
Latency tolerance dependent on
- tempo and onset synchronization: Hindemith *Sonata No.4* (mvt1 vs final mvt)
- timbre of instrument: Piazzolla's *Le Grand Tango* (accordion 25ms vs piano 100ms)

Sense of acoustic presence made more "natural" by 10.2-channel audio
Perspective differences require recording of experience at both sites

2002

Jun — Remote Media Immersion (RMI) Initial Demonstration
Oct — Internet2 Meeting: Large Room RMI Demonstration
Dec — **DIP v.0: Distributed Duet** (audio only)

2003

Jan — Recording from Streams
Jan — **Remote Master Class with New World Symphony**
Jun — **DIP v.1: Duet with Audience** (audio/video unsynch)

2004

Jan — Two-Way Live HD Streaming LA, Hawaii, Miami Experiments
Feb-Apr — **DIP v.2: Two-Way Baseline User Studies**
May — **A:** first time players perform under delayed conditions
B: player 1 and player 2 swap parts (symmetry test)
Jun — **C:** players practice to compensate for delay
D: players perform with both partner and self delayed
Sep — One-Way Live HD Streaming on Internet2: Austin, Texas

USC Viterbi School of Engineering

REMOTE MASTERCLASS (2003)

Student at the New World Symphony in **Miami Beach**

Ron Leonard cellist of the LA Philharmonic at **USC**

TECHNOLOGY
10.2 immersive audio by Kyriakakis and Holman
Off-the-shelf video software/hardware (Star Valley MPEG2 codecs), large delays

RESULT
Teacher reports improved presence with immersive audio: "student was really there"

2002

Jun — Remote Media Immersion (RMI) Initial Demonstration
Oct — Internet2 Meeting: Large Room RMI Demonstration
Dec — **DIP v.0: Distributed Duet** (audio only)

2003

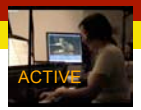
Jan — Recording from Streams
Jan — **Remote Master Class with New World Symphony**
Jun — **DIP v.1: Duet with Audience** (audio/video unsynch)

2004

Jan — Two-Way Live HD Streaming LA, Hawaii, Miami Experiments
Feb-Apr — **DIP v.2: Two-Way Baseline User Studies**
May — **A:** first time players perform under delayed conditions
B: player 1 and player 2 swap parts (symmetry test)
Jun — **C:** players practice to compensate for delay
D: players perform with both partner and self delayed
Sep — One-Way Live HD Streaming on Internet2: Austin, Texas

USC Viterbi School of Engineering

DIP v.1 - DUET WITH AUDIENCE (2003)



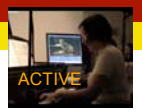
Elaine Chew in **Ramo Hall** w earphone and video monitor

Dennis Thurmond **Powell Hall** with audience, 10.2 immersive audio and Large screen HD image

TECHNOLOGY
Video: NTSC resolution, 31 Mb/s DV, software decode,
one-way latency: 110ms + <5ms (compression + network)
Audio: uncompressed, 16 or more channels at 1 Mb/s each,
one-way latency: <10ms + <5 ms (processing + network)

USC Viterbi School of Engineering

DIP v.1 - DUET WITH AUDIENCE (2003)



Elaine Chew in **Ramo Hall** w earphone and video monitor

Dennis Thurmond **Powell Hall** with audience, 10.2 immersive audio and Large screen HD image

EXPERIMENT

Piazzolla's *Le Grand Tango*

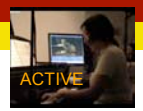
Approximate tempo is 120bpm

Granularity of events is at 16th-note level, i.e. IOI = 125ms

Even 60ms RT delay could be debilitating.

USC Viterbi School of Engineering

DIP v.1 - DUET WITH AUDIENCE (2003)



Elaine Chew in **Ramo Hall** w earphone and video monitor

Dennis Thurmond **Powell Hall** with audience, 10.2 immersive audio and Large screen HD image

WHAT WE LEARNED

Video delay made it unusable as source of cues for synchronization. Audio (<<50ms RT delay) was used.

Musicians compensated for delay by anticipating each other's actions and scaling back on spontaneity (low risk performance). Some artistic licence was exercised to "make ends meet."

Co-location of audience with one musician caused imbalance in control. No matter what happened, performer at the audience site had to make the final performance "work".

2002

Jun — Remote Media Immersion (RMI) Initial Demonstration

Oct — Internet2 Meeting: Large Room RMI Demonstration

Dec — **DIP v.0: Distributed Duet** (audio only)

2003

Jan — Recording from Streams

Jan — **Remote Master Class with New World Symphony**

Jun — **DIP v.1: Duet with Audience** (audio/video unsynch)

2004

Jan — Two-Way Live HD Streaming LA, Hawaii, Miami Experiments

Feb-Apr — **DIP v.2: Two-Way Baseline User Studies**

May — **A:** first time players perform under delayed conditions

B: player 1 and player 2 swap parts (symmetry test)

Jun — **C:** players practice to compensate for delay

D: players perform with both partner and self delayed

Sep — One-Way Live HD Streaming on Internet2: Austin, Texas

USC Viterbi School of Engineering

DIP v.2 - TWO-WAY BASELINE USER STUDIES (2004)

The **Objective**: To measure and document qualitatively and quantitatively the effects of delay and other variables on immersion, usability, and quality in the Distributed Immersive Performance scenario

A: first time players perform under delayed conditions

B: player 1 and player 2 swap parts (symmetry test)

C: players practice to compensate for delay

D: players perform with both partner and self delayed

USC Viterbi School of Engineering

DIP v.2 - TWO-WAY BASELINE USER STUDIES (2004)

Tosheffpianoduo.com

Vely Stoyanova and Ilia Tosheff (piano duo since 1997)
The first piano duo to audition and be offered admission to the Thornton School of Music
Pioneers in the *Protégé Program* (see Chris Sampson for details)

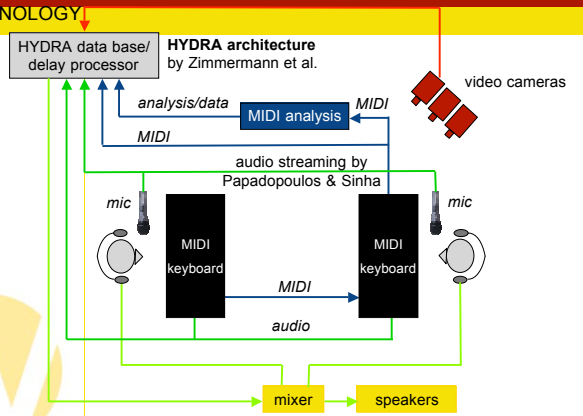
Described by critics and press as
"...*brilliant concert artists*..."
"...*captivating stage presence*..."
"...*fascinating temperament*..."
"...*charm and spontaneity that grabs the audience*..."

THE GRAND PRIZE – Tokyo, Japan • THE GRAND PRIZE – Dobrich, Bulgaria • FIRST PRIZE – Rome, Italy FIRST PRIZE – Rome, Italy • FIRST PRIZE – Sofia, Bulgaria • WINNERS – Zaragosa, Spain • WINNERS – Michigan, USA • WINNERS – Miami, USA • WINNERS – Los Angeles, USA • MUSICIAN OF THE YEAR in Bulgaria • PREMIO "Zinetti" – Verona, Italy • PREMIO "V.Bellini" – Caltanissetta, Italy • PRIZE – Groningen, Holland • PRIZE – Sofia, Bulgaria

USC Viterbi School of Engineering

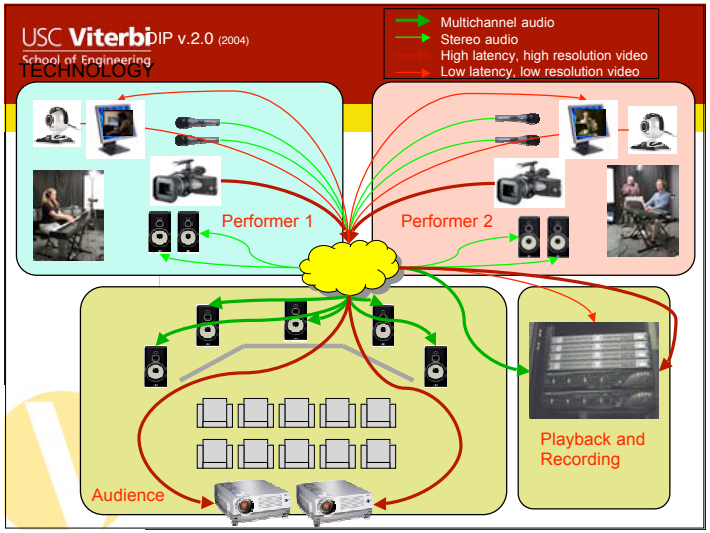
DIP v.2 - TWO-WAY BASELINE USER STUDIES (2004)

TECHNOLOGY



USC Viterbi School of Engineering DIP v.2.0 (2004)

TECHNOLOGY



USC Viterbi School of Engineering

DIP v.2 - TWO-WAY BASELINE USER STUDIES (2004)

EXPERIMENTS

Poulenc *Sonata for Piano Four-Hands*

- *Prelude* (tempo = 132 bpm)
- *Rustique* (tempo = 46 bpm)
- *Finale* (tempo = 160 bpm)

Questions:

- How would you rate the ease of ensemble playing?
- How would you rate the ease of creating a musical interpretation?
- How would you rate the ease of adapting to this condition?

Debriefing, observations

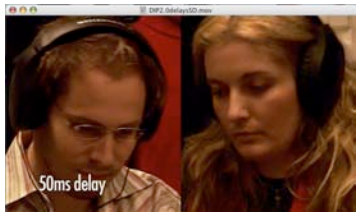
Quantitative measures of musical synchronization (Chew et al.)

USC Viterbi School of Engineering

DIP v.2 - TWO-WAY BASELINE USER STUDIES (2004)

A: first time players perform under delayed conditions
B: player 1 and player 2 swap parts (symmetry test)

Two players in same room facing each other (visual delay 0ms)
Variable audio delay: 0, 10, 20, 30, 40, 50, 75, 100, 150ms



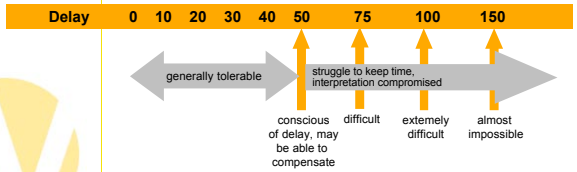
VIDEO 1: DELAYS
VIDEO 2: PERSPECTIVES
VIDEO 3: COMMENTS

USC Viterbi School of Engineering

DIP v.2 - TWO-WAY BASELINE USER STUDIES (2004)

A: first time players perform under delayed conditions
B: player 1 and player 2 swap parts (symmetry test)

Two players in same room facing each other (visual delay 0ms)
Variable audio delay: 0, 10, 20, 30, 40, 50, 75, 100, 150ms

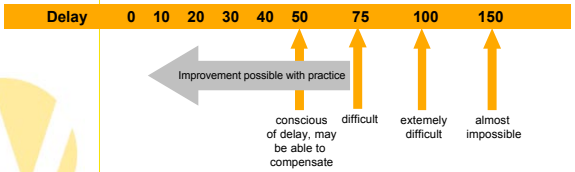


USC Viterbi School of Engineering

DIP v.2 EXPERIMENTS A & B (2004)

A: first time players perform under delayed conditions
B: player 1 and player 2 swap parts (symmetry test)

Two players in same room facing each other (visual delay 0ms)
Variable audio delay: 0, 10, 20, 30, 40, 50, 75, 100, 150ms



USC Viterbi School of Engineering

DIP v.2 EXPERIMENTS C & D (2004)

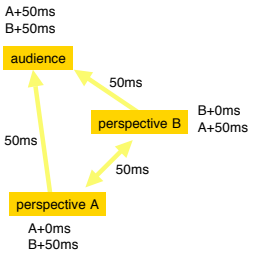
C: players practice to compensate for delay
D: players perform with both partner and self delayed

Two players in same room facing each other (visual delay 0ms)
Variable audio delay **C**: 20 - 100ms
Variable audio delay **D**: 50, 55, 60, 65, 70, 75ms

USC Viterbi School of Engineering

DIP v.2 EXPERIMENTS C & D (2004)

C: players practice to compensate for delay
D: players perform with both partner and self delayed

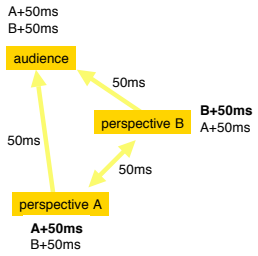


USC Viterbi School of Engineering

DIP v.2 EXPERIMENTS C & D (2004)

C: players practice to compensate for delay
D: players perform with both partner and self delayed

"I want to hear what the other person hears"



USC Viterbi School of Engineering

DIP v.2 EXPERIMENTS C & D (2004)

C: players practice to compensate for delay
D: players perform with both partner and self delayed

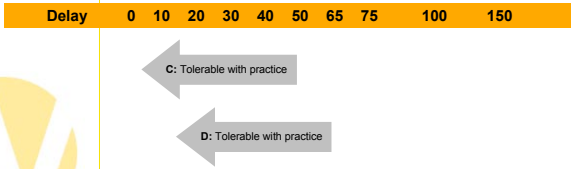
Two players in same room facing each other (visual delay 0ms)
Variable audio delay **C**: 20 - 100ms
Variable audio delay **D**: 50, 55, 60, 65, 70, 75ms

USC Viterbi School of Engineering

DIP v.2 EXPERIMENTS C & D (2004)

C: players practice to compensate for delay
D: players perform with both partner and self delayed

Two players in same room facing each other (visual delay 0ms)
Variable audio delay **C**: 20 - 100ms
Variable audio delay **D**: 50, 55, 60, 65, 70, 75ms



USC Viterbi School of Engineering

AGENDA

- **Introduction**
- **From score to performance**
  - Example: structure-expression link
  - Interpreting Child's *Epilogue*
- **Making performances**
  - ESP: the expression synthesis project
- **Collaborative performance**
  - DIP: distributed immersive performance
- **Related presentations at ISMIR**

USC Viterbi School of Engineering

REFERENCES-1

Bamberger, J., "What Develops in Musical Development?," manuscript, April 17, 2005.

Chew, E., R. Zimmermann, A. A. Sawchuk, C. Kyriakakis., C. Papadopoulos, A. François, G. Kim, A. Rizzo and A. Volk, "Musical Interaction at a Distance: Distributed Immersive Performance," in Proceedings of MUSICNETWORK 2004.

Chew, E., A. R. J. François, J. Liu and A. Yang, "ESP: A Driving Interface for Musical Expression Synthesis," in Proceedings of NIME 2005.

Chew, E., A. Sawchuk, R. Zimmermann, the Tosheff Piano Duo, C. Kyriakakis, C. Papadopoulos, A. François, A. Volk, "Distributed Immersive Performance," in Proceedings of NASM, 2004.

Chew, E., R. Zimmermann, A. Sawchuk, C. Papadopoulos, C. Kyriakakis, C. Tanoue, D. Desai, M. Pawar, R. Sinha, W. Meyer, "A Second Report on the User Experiments in the Distributed Immersive Perofrmance Project," in Proceedings of MUSICNETWORK 2005.

USC Viterbi School of Engineering

REFERENCES-2

Dixon, S., W. Goebl and G. Widmer, "The 'Air Worm': an interface for real-time manipulation of expressive music performance," in Proceedings of ICMC 2005.

Dixon, S., "An On-Line Time Warping Algorithm for Tracking Musical Performance," in Proceedings of IJCAI 2005.

Dixon, S., and G. Widmer, "MATCH: a music alignment tool chest," in Proceedings of ISMIR 2005.

François, A. R. J., "A Hybrid Architectural Style for Distributed Parallel Processing of Generic Data Stream," in Proc. of ICSE 2004.

Palmer, C., "Music Performance," Ann. Rev. Psych. 1997, 48:115-38.

Raphael, C., "Aligning Musical Scores with Audio using Hybrid Graphical Models," in Proceedings of AAAI 2004.

Raphael, C., "Orchestral Musical Accompaniment from Synthesized Audio," in Proceedings of ICMC 2003.

Sawchuk, A. A., E. Chew, R. Zimmermann, C. Papadopoulos and C. Kyriakakis. "From Remote Media Immersion to Distributed Immersive Performance," in Proceedings of the ACM SIGMM 2003 Workshop on Experiential Telepresence, 2003.

Widmer, G., S. Dixon, W. Goebl, E. Pampalk and A. Tobudic, "In Search of the Horowitz Factor," AI Magazine, 2003.

USC Viterbi School of Engineering

RESOURCES

More papers can be found at
- *www-rcf.usc.edu/~echew/bibliography*

Music Computation and Cognition Lab
- *www-rcf.usc.edu/~mucoaco (under construction)*

Engineering Approaches to Music Cognition
- *www-scf.usc.edu/~ise575*

ACKNOWLEDGEMENTS

The ESP and DIP projects were funded in part by the National Science Foundation (NSF) Career Grant No. 0347988, and by the Integrated Media Systems Center, an NSF Engineering Research Center Cooperative Agreement No. EEC-9529152. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect those of NSF.