Siggraph Asia 2011 Course on:
Advances in New Interfaces for Musical Expression

Sidney Fels
University of British Columbia
Michael Lyons
Ritsumeikan University

Laptop Performance

A NIME Performance

What is NIME about?

The Problem:

- Digital Technology & computers involved in nearly all forms of contemporary music

- But the computer is not a Musical Instrument

The "Office Gesture"

Laptop Battle Tokyo
Superdeluxe Roppongi
11/2008

sml!

How to Play the Computer?

- Computers offer a wide range of sound and music creation opportunities
- How can we create new interfaces to play computers in a way that is appropriate to human brains & bodies?

How to Play the Computer?

This tutorial is all about progress in human-computer interfaces for making music from past NIMEs

Objectives

1. introduce the theory and practice of NIME
2. NIME community is very accessible and growing
3. get to know some of the people of NIME
4. easy to start creating NIMEs and a lifetime of enjoyment to master
5. musical expression transcends gender and culture
6. if you are not having fun, it's probably not for you

A Brief History of NIME

"New Interfaces for Musical Expression"
First organized as a workshop of ACM CHI'2001
Experience Music Project - Seattle, April, 2001
Lectures/Discussions/Demos/Performances

A Brief History of NIME

NIME-02 - Media Lab Europe, Dublin in May 2002

Conference-scale event with similar format to the NIME-01 workshop

… since 2001

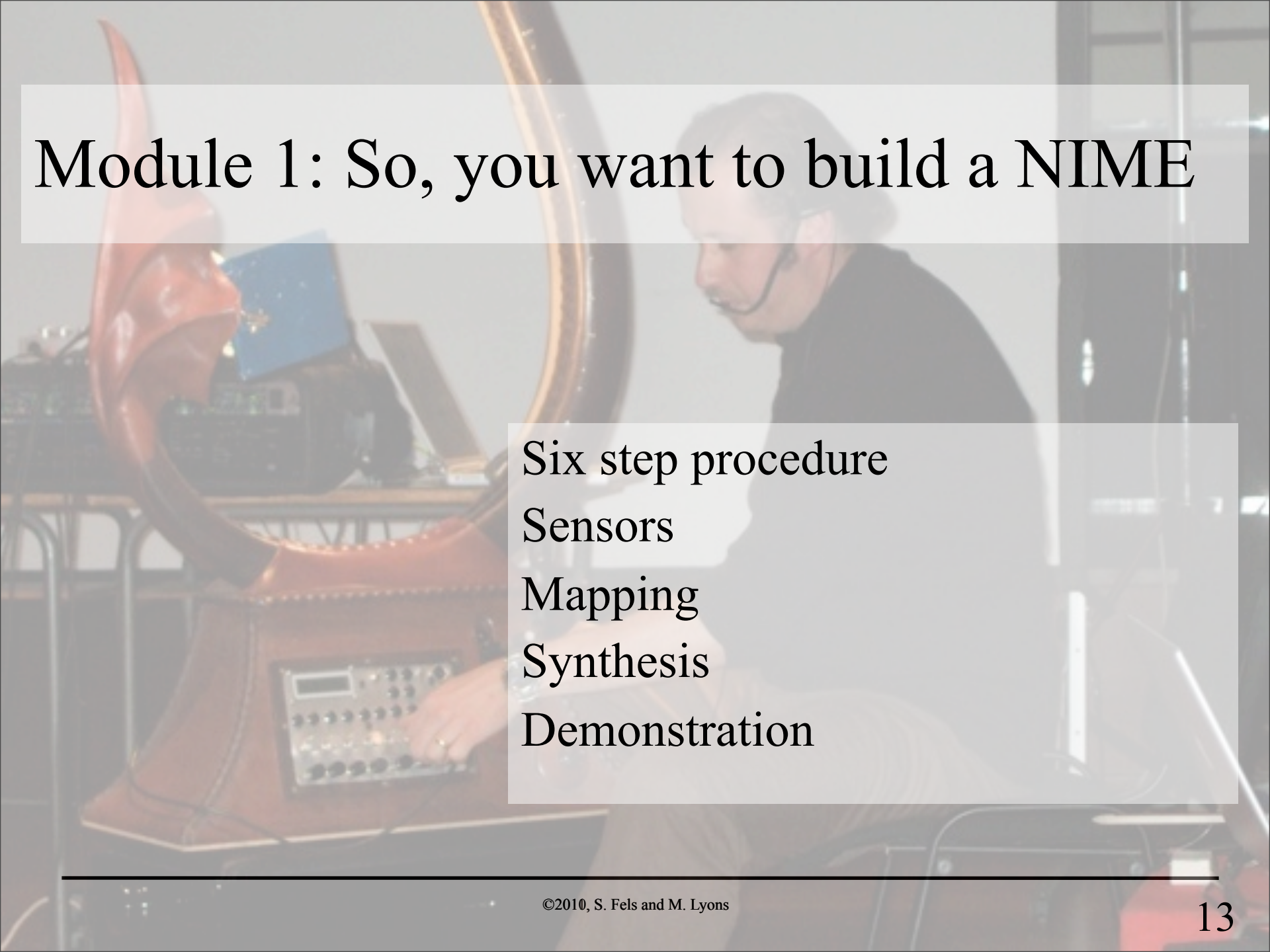
NIME Themes

- Novel controllers & interfaces
- Performance & composition with new interfaces
- Interfaces for collaborative performance
- Real-time gestural control of music
- Interfaces for musical novices & education
- Cognition in Musical Interface Design
- Haptic & force feedback in musical control
- Artistic, cultural, and social impact

Course structure

- Part I - 2:00 - 3:20
  - Module 1: So you want to build a NIME…
  - Module 2: Camera-based Interfaces
  - Module 3: Design & Aesthetics of NIME
  - Discussion (if time)
- Break 3:20 - 3:35
- Part II - 3:35 - 5:15
  - Module 4: NIME after NIME
  - Module 5: NIME Theory
  - Module 6: NIME Education
  - Discussion

Module 1: So, you want to build a NIME



Six step procedure

Sensors

Mapping

Synthesis

Demonstration

Six steps to build a NIME

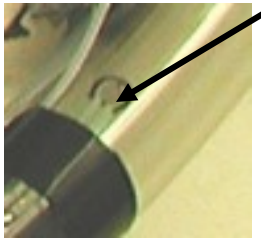
1. Pick control space
2. Pick sound space
3. Pick mapping
4. Connect with software
5. Compose and practice
6. Repeat

1 and 2 often switched.

Tools to help with steps 1-4.

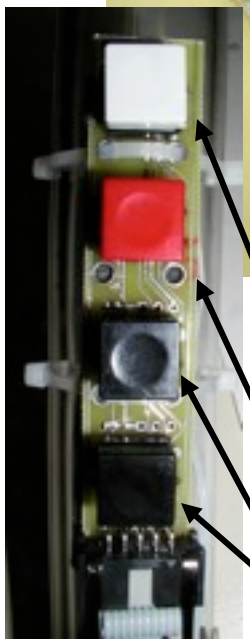
An example: Tooka *(Fels et al., 2004)*

Vibrato



Pitch Bend

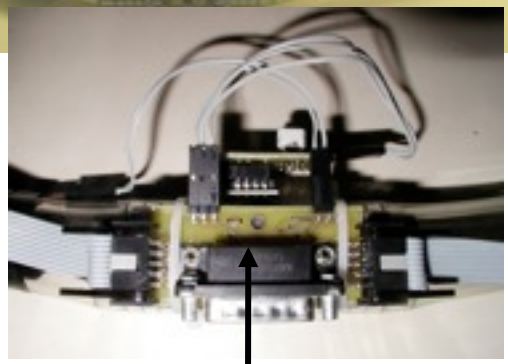
mapping with PureData



Octave

Sustain

Pitch



Volume

sound synthesis

Pick your control space

- Plethora of sensors available to measure:
  - motion of body parts
    - position, rotation, velocity and acceleration
  - translation and rotation (torque) forces
    - isometric and isotonic sensors
  - pressure
  - airflow
  - proximity
  - temperature
  - neurophysiological signals
    - heart rate
    - galvanic skin response
    - brain waves
    - muscle activities
  - light levels
  - and more…

Physical property sensors

- Piezoelectric Sensors
- Force Sensing Resistors
- Accelerometer (Analog Devices ADXL50)
- Biopotential Sensors
- Microphones
- Photodetectors
- CCDs and CMOS cameras
- Electric Field Sensors
- RFID
- Magnetic trackers (Polhemus, Ascension)
- and more…

What can I measure?

Human Action Oriented Sensors

- Here's a few:
  - Bend - piezo-resistive
  - Close - IR reflection, 1-7"
  - FarReach - ultrasonic (50Hz update)
  - Flash - phototransistor
  - Gforce - piezo-electric single axis accelerometer
  - Hot - zener effect (thermocouple)
    - -40 to 100deg C
  - Light - photo-resistive

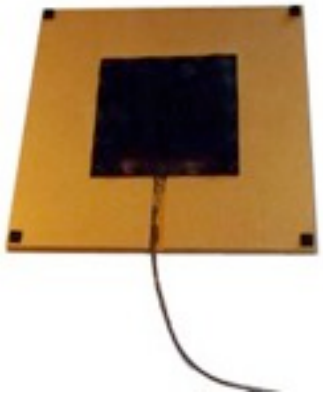





How do I measure that?

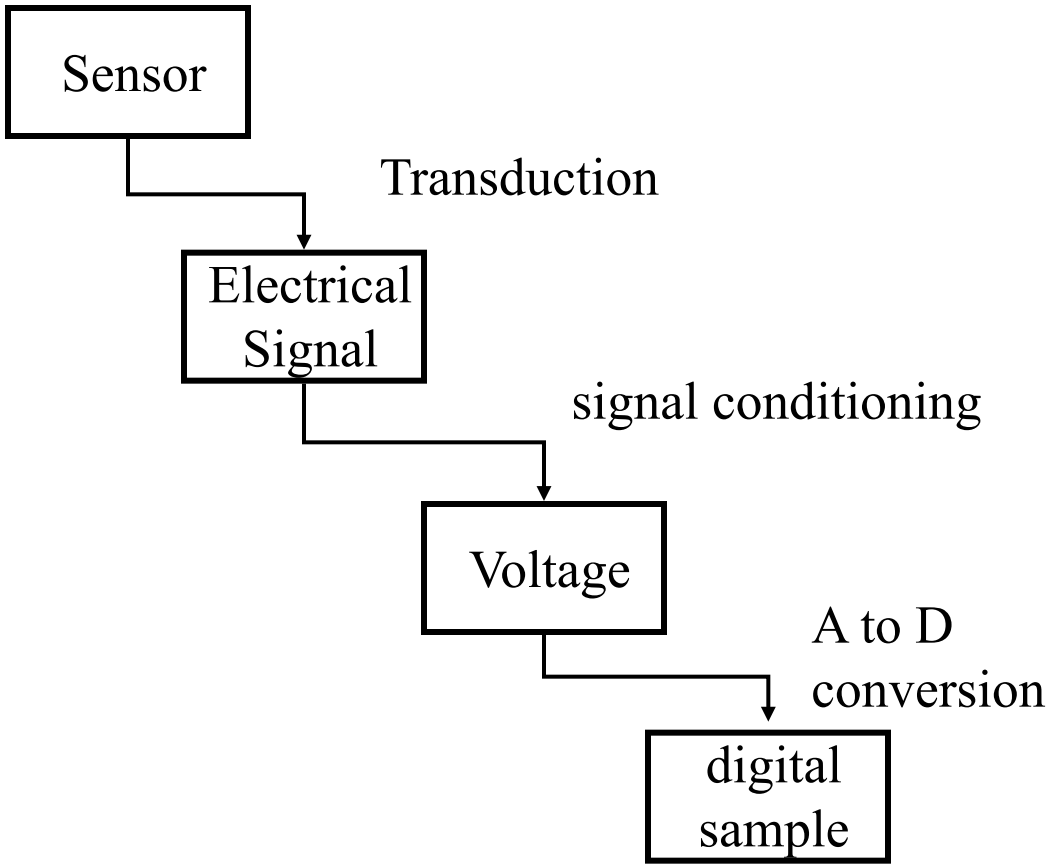
Human Action Oriented Sensors

- Reach - EMF disturbance
- Slide - resistive
- TapTile - Force sensitive resistor
- Tilt
  - electrolytic, single axis (-70-+70 deg)
- Touch - 0 travel FSR
- TouchGlove
  - several touch sensors
- TouchStrip
  - long touch sensor
- Turn
  - potentiometer



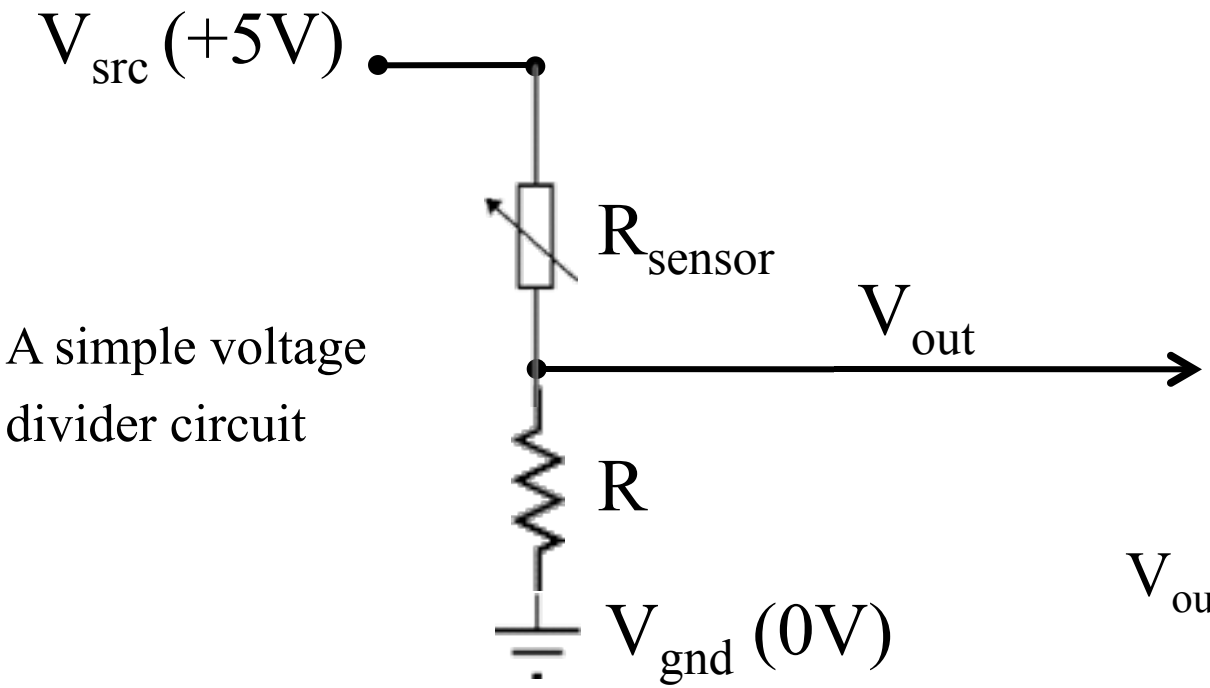
Connecting sensors

- Sensor response requires transduction and digitizing:
  - electrical
    - voltage
    - resistance
    - impedance
  - optical
    - colour
    - intensity
  - magnetic
    - induced current
    - field direction
  - mechanical force



Digitizing

- converting change in resistance into voltage
  - typical sensor has variable resistance (R_{sensor})



A simple voltage divider circuit

$$V = RI$$

$$V_{out} = \frac{V_{src} * R}{(R_{sensor} + R)}$$

Digitizers for Connecting to Computer

- Some MIDI synthesizers, i.e., Yamaha mu100
- Arduino board
  - Bluetooth module for wireless A/D
- ICubeX
  - A/D to MIDI
- Phidgets
  - A/D to USB
- DAQ boards
  - A/D to computer bus

Mapping Sensor to Music

- The relationship between the change in the sensor value to the sound output is called a *mapping*
- The mapping defines how much effort to learn and play your NIME
- Last step is to control your sound output:
  - communication protocol
  - sound synthesizer

This is the heart of the course and what NIME community is specialized in.

Sound output control: communications

- Musical Instrument Digital Interface (MIDI)
  - electronic instrument standard defined in 1982
  - specifies;
    - connectors, data rates, electrical properties, etc.
  - 1 message/msec (approx)
    - note on/off, velocity is typical packet
    - control messages to change instrument synthesis

- Open Sound Control (OSC) *(Wright and Freed, 1997)*
  - TCP/IP, internet protocol, typically UDP based
  - faster, low latency, variable packet types
  - computer to computer, computer to hardware
- Internal protocols, i.e. DAQ driver

Sound Synthesis Techniques

- Methods
  - sampled
  - FM synthesis
  - additive/subtractive
  - granular
  - waveguide/physical modeling
  - scan

- check out *Computer Music Tutorial*, Roads, C., MIT Press, 1996

Sound Synthesizers

- Hardware MIDI synthesizers
  - Yamaha, Roland, Korg, Casio, Moog, Kowai, Symbolic Sound Corporation, Nord modular, and others
- Software
  - STK (Cook)
  - PureData (Pd, Puckette)
  - JASS (van den Doel)
  - Max/MSP (cycling74.com)
  - Chuck (Wang and Cook, 2003)
  - Supercollider (McCartney, 1996)
  - and others

A few practical notes

- Portable:
  - Batteries can be used to make portable
  - Wireless protocols available for portable
- Write pieces for the instrument
- Aesthetics are important
- Plan your checklist for performance
  - too many things can go wrong with technology
- Plan your staging
  - can severely impact performance of sensors
- Plan for producing stable versions
  - hard to learn to play if NIME keeps changing

Module 3 has more details.

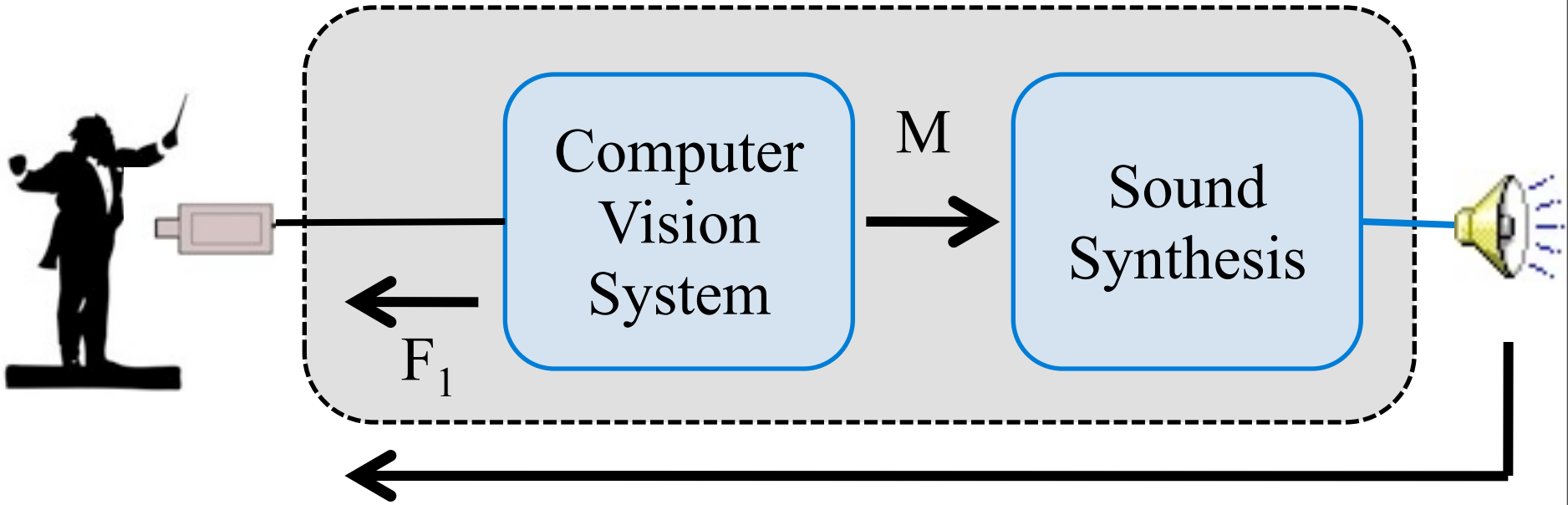
Summary

- Making a NIME is usually easier than playing it (well)
- Choose your:
  - movement type
  - sound space
  - sensing
- Put together your input, mapping and output
- Now you are ready to:
  - practice, practice, practice and perform…
  - aesthetic principles covered in module 3

Module 2: Camera-based Interfaces

- Imaginary Piano: visual input only
- Iamascope: visual input and output
- Facial gesture musical interfaces: when vision may be your best option
- Reactable: vision + (passive) touch, through alignment)

Camera-based Interfaces



F_1 : visual feedback in the form of aligned graphics

Imaginary Piano: No visual feedback

Leonello Tarabella, NIME-02

- Video camera with motion-sensitive zone
- No primary feedback

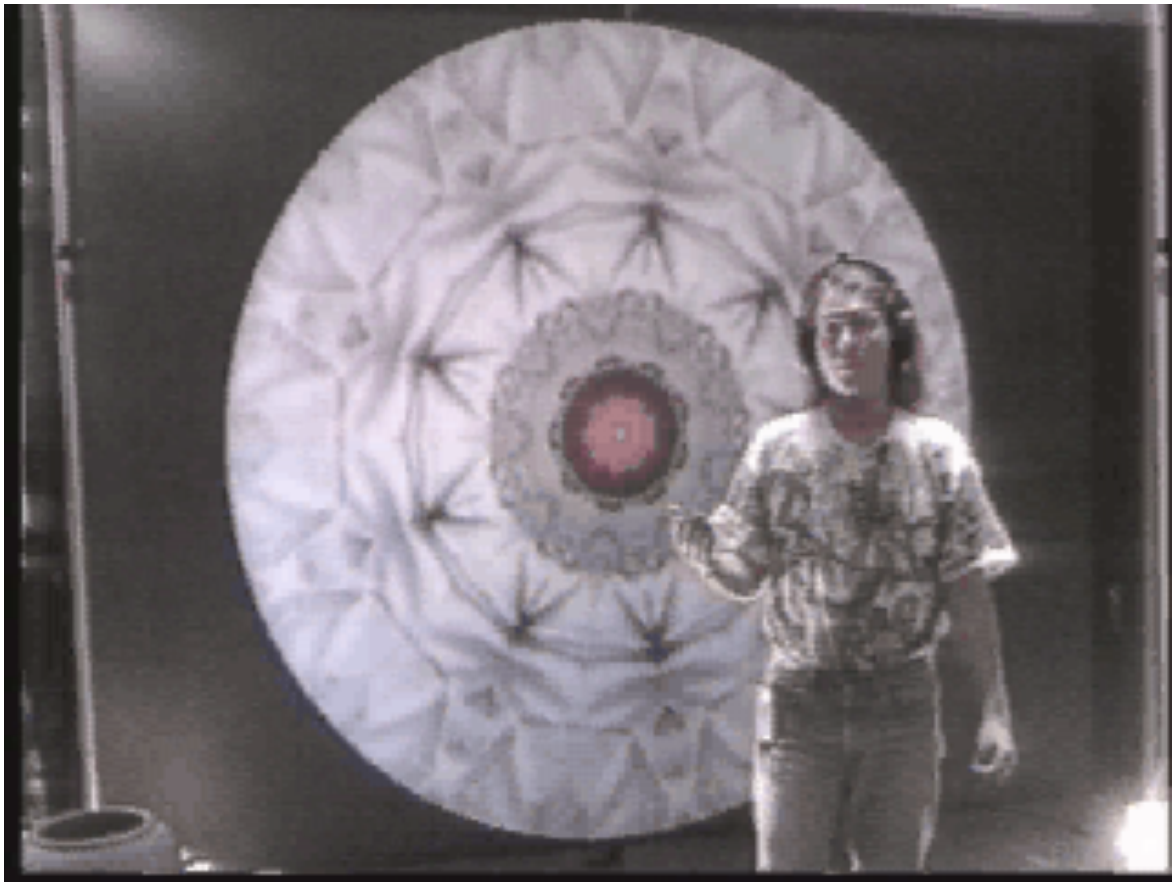
Visual Input Only: Imaginary Piano

Leonello Tarabella, NIME-02

Visual Input & Output

- Iamascope
- This gives a colourful kaleidoscopic feedback of part of the player. Gestures are used to trigger harmonious chord progressions and arpeggios.
- Quite good coordination between sound and graphics

Iamascope - video



Facial Gesture Musical Interface

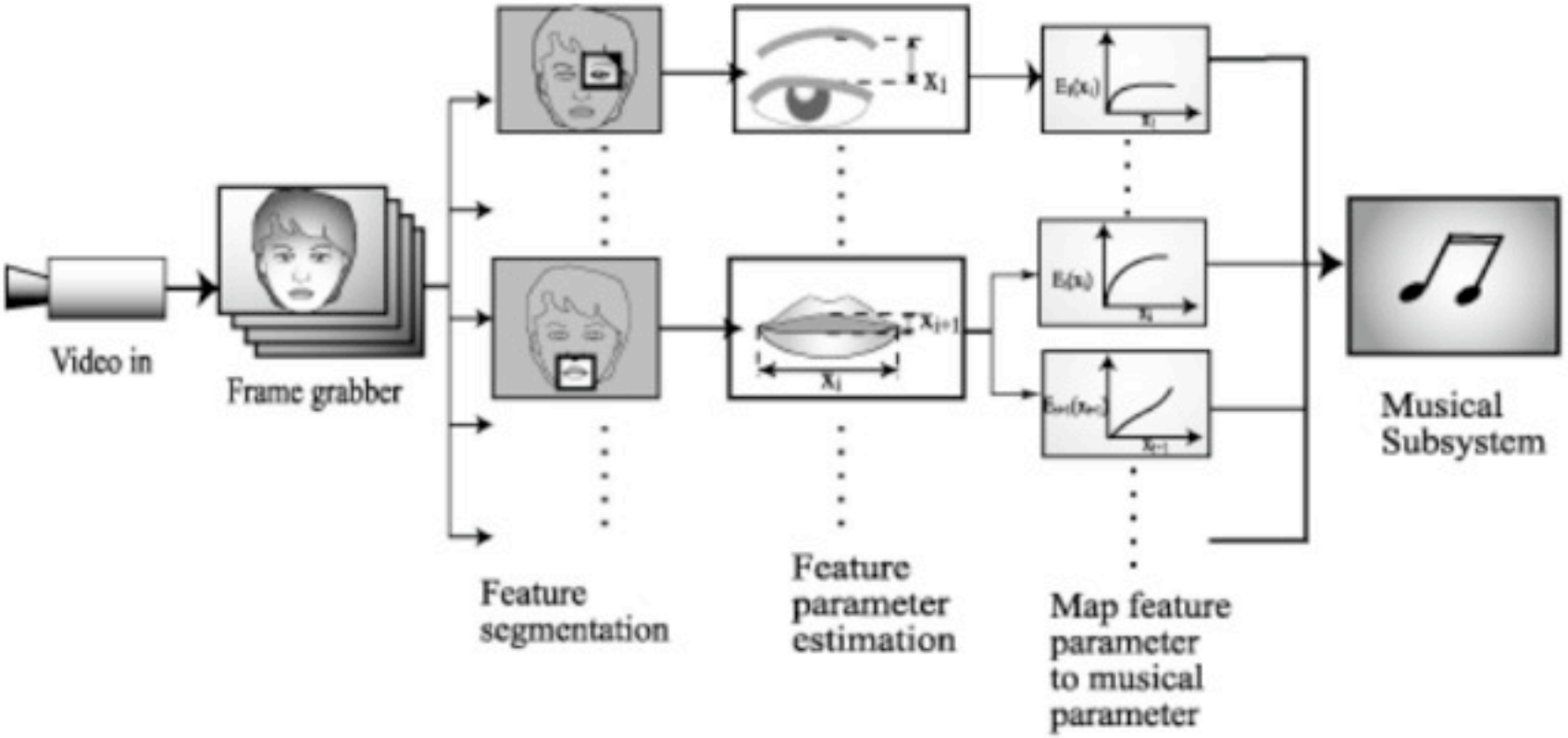
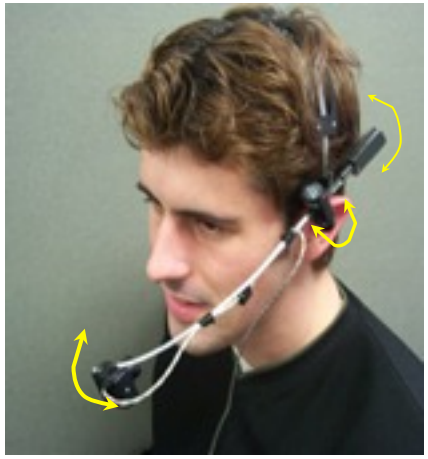


Figure 2 Schematic of the facial action driven musical controller.

Lyons, NIME-01

Mouthesizer



- Colour & intensity thresholding
- Morphological transform & filtering
- Connected components + shape analysis

} Image processing operations

Lyons et al., NIME-03

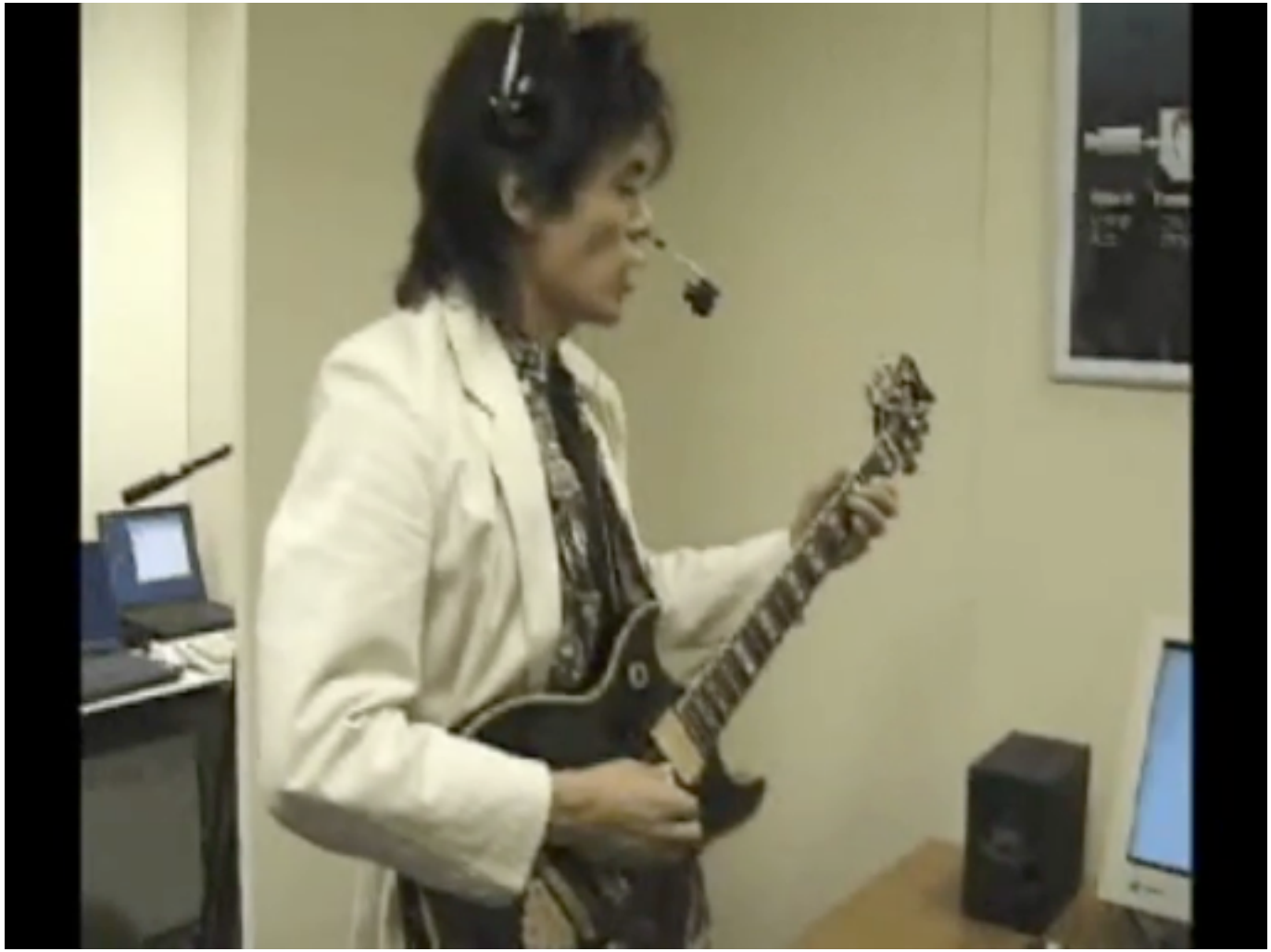
Mouthesizer Video
Guitar Effects Controller

Lyons (2001)

Mapping:

H ⎫ Cutoff Frequency of Resonant Low Pass Filter
W ⎭ Distortion

Mouthesizer Video
Guitar Effects Controller



Sonification of Facial Actions (SoFA)

- Optical Flow triggers samples
- Samples mapped to facial zones
- Frame is recalibrated with face detection “Saccades”

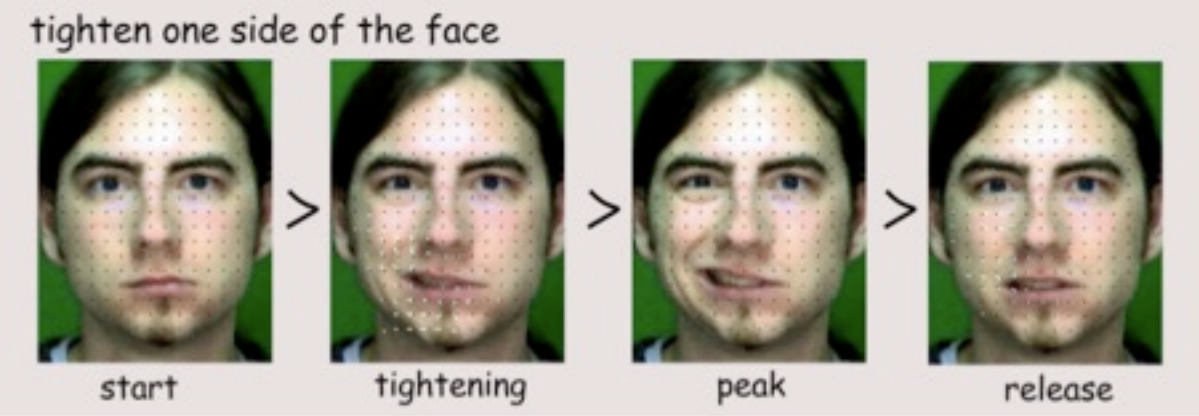


Figure 2 Sample facial action with associated optic flow vector fields illustrated as white line segments.

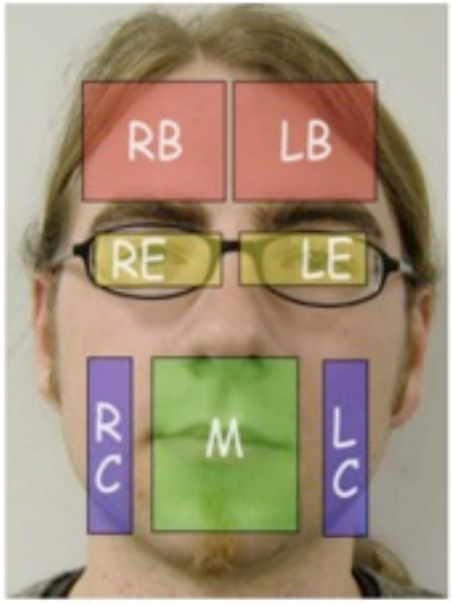


Figure 3. Facial Zones used to trigger MIDI events.

Funk et al., NIME-05

Sonification of Facial Actions (SoFA)

Reactable

- Video tracking of marked pucks on a table
- Projection of visual feedback

- Sergi Jordà et al., Universitat Pompeu Fabra
- first presented at NIME-03

Reactable

3D Vision Interfaces

- OpenKinect

Summary

- Large number of works have used visual input and output as a way to enhance new musical interfaces
- General principle is that vision offers a powerful way to capture gestural input
- Visual output using camera input can provide transparency

Module 3: Design & Aesthetics of

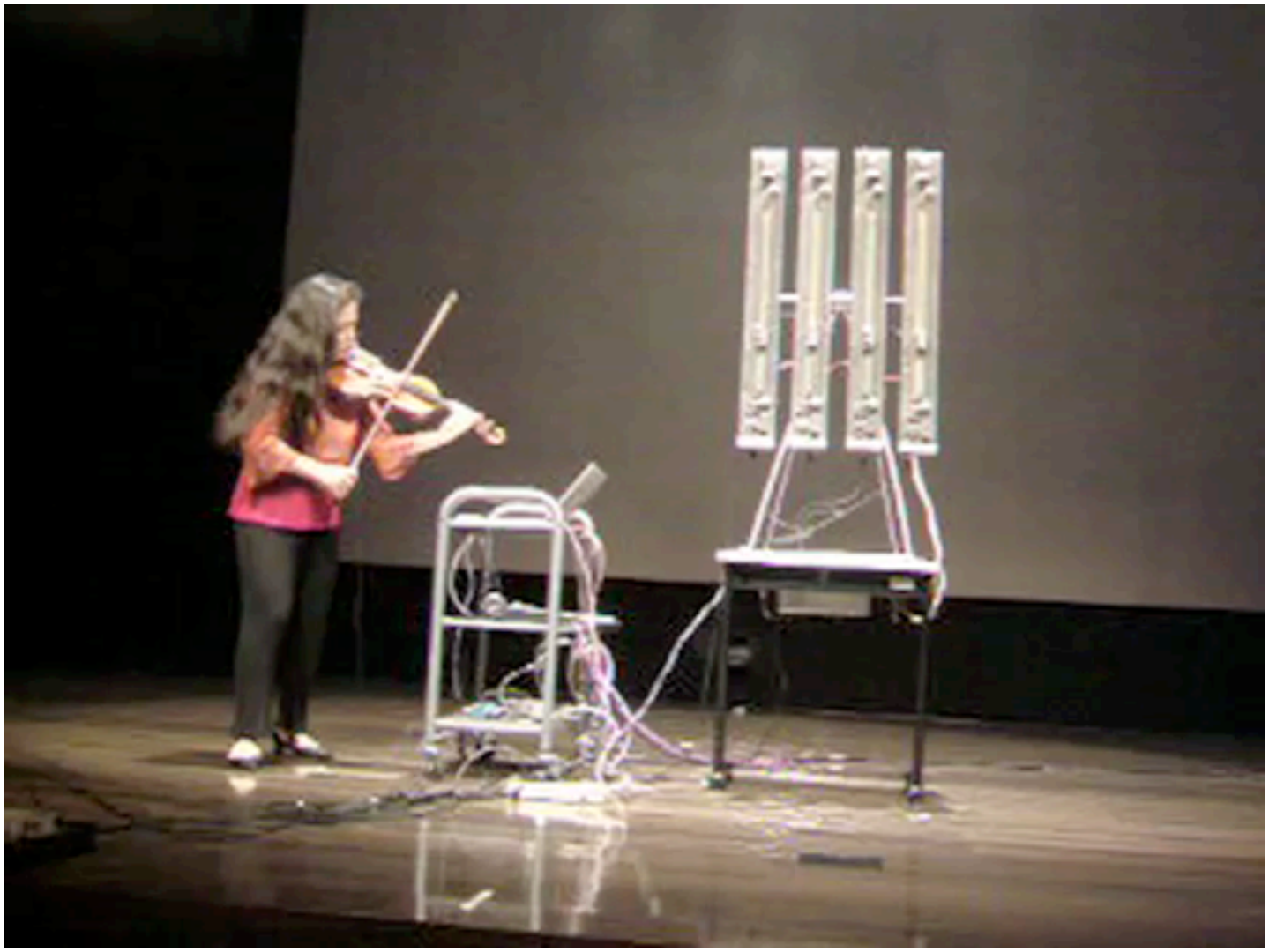
- Technological Expressionism
- NIME & the Music Process
- Challenge of Performance
- Mapping & the Audience: Transparency
- Visual Feedback
- Interaction Metaphor
- Perry's principles

Kanta Horio - "Particle"

Technological Expressionism

- Shock of the New
- Human-machine relationship
- Techno-fetishism
- Experimentalism

Mari Kimura w/ Lemur Guitarbot



NIME Favors a Return to Process-oriented Music

- "…we are in a period of restoring fluidity to the musical transformative process – of making music more process-oriented again and less artifact-oriented." *Gideon D'Arcangelo, NIME-04*

20th century

21st

New Folk?

hrdrockgrrl's Channel Subscribe

hrdrockgrrl
Joined: **09 September 2006**
Last Sign In: **1 week ago**
Videos Watched: **3,586**
Subscribers: **171**
Channel Views: **6,451**

I'm an amateur musician. My main instruments are jazz piano and bluegrass mandolin, though I also play guitar and cornet.

City: **Los Angeles**
Country: **United States**

Report profile image violation

Oh Shenandoah played on iPhone ocarina
From: hrdrockgrrl
Views: 25,959
Comments: 59

Challenge of Performance

- Audience may not understand your NIME
- Expectations may be varied
- No musical tradition to fall back on
- A demo is not a performance

Hisashi Okamoto, NIME-04
The First Sailing with Limber-Row

Hisashi Okamoto - Limber Row

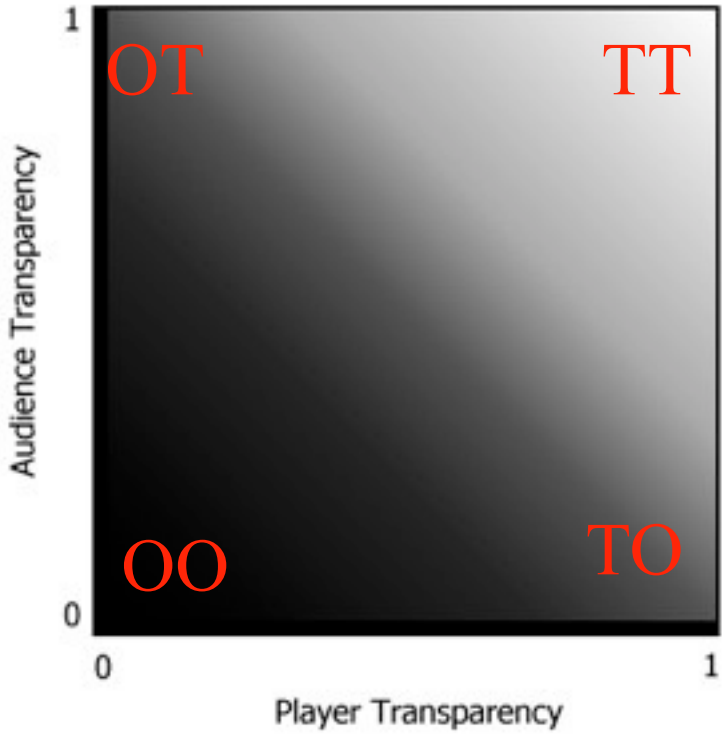
Transparency for Performer & Audience

- Complicated mapping → OO
- Simplify → OT
- Complex mapping → TO

T = transparent

O = opaque

How to achieve → TT?

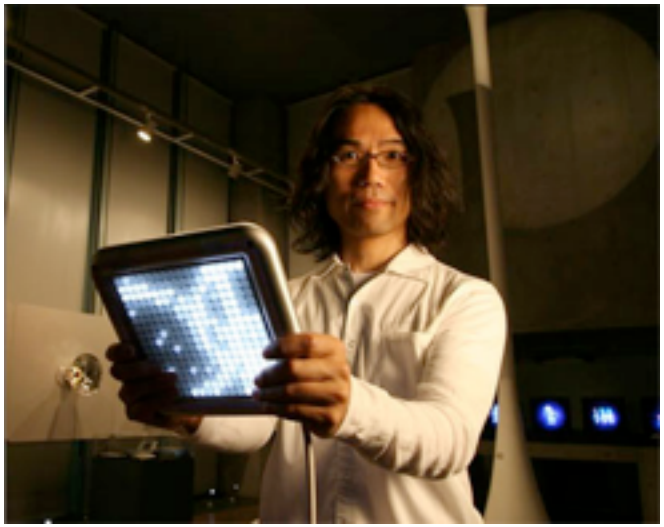


(Gadd et al, 2003)

Visual Cues & Transparency

- Visual Appearance of Instrument
- Visualization of Interaction
- Visualization of Sound Output

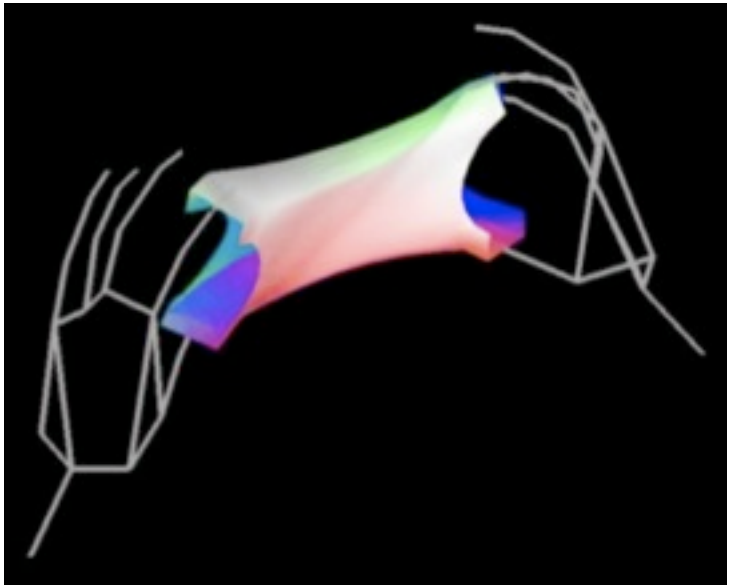
Reactable



Tenori-on

Transparency & Interaction Metaphor

- SoundSculpting *(Mulder and Fels, 1998)*
  - two Cybergloves and Trackers
  - map metaphor of rubber sheet onto sound space
  - transparent for audience and performer



Transparency
Simple & Direct Interface

Particle

Kanta Horio, NIME-04

- Contact Mics
- Magnets
- Paper clips

Aesthetics of Failure

- Suspense highlights the technological challenge
- If there are never difficulties, glitches etc… then the limits are not being pushed

Some Design Guidelines: Perry's Principles

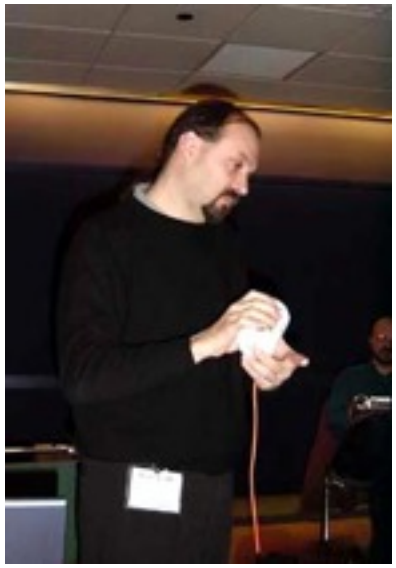
- Rules of thumb for the design of digital musical instruments
- Several of the principles are heavily subscribed

"Principles for Designing Computer Music Controllers" *P. Cook, NIME-01*

Revised:

"Principles for Controlling Computer Music Designers" *P. Cook, Keynote talk,*

Perry's Principles



Human/Artistic Principles

P1: Programmability is a curse

P2: Smart instruments are often not smart

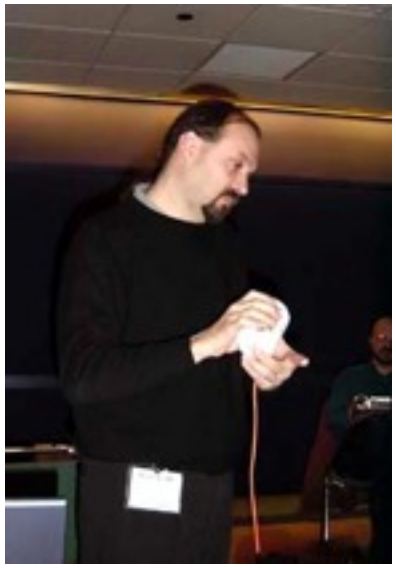
P3: Copying an instrument is dumb, leveraging expert technique is smart

P4: Some players have spare bandwidth, some do not

P5: Make a piece, not an instrument or controller

P6: Instant music, subtlety later

Perry's Principles



Human/Artistic Principles

P1: Programmability is a curse

P2: Smart instruments are often not smart

P3: Copying an instrument is dumb, leveraging expert technique is smart

P4: Some players have spare bandwidth, some do not

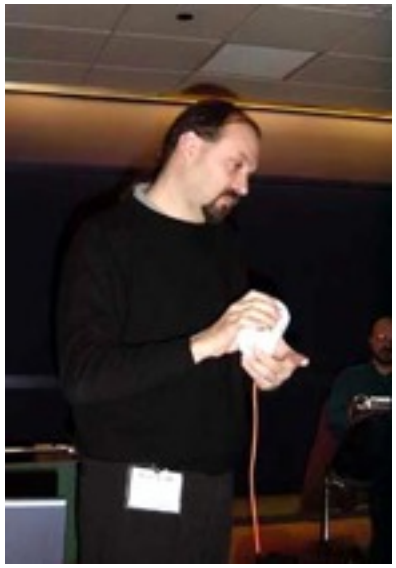
P5: Make a piece, not an instrument or controller

P6: Instant music, subtlety later

P1: Programmability is a curse
P2: "Smart" Instruments are Often Not

- "Easy to add complexity, features, bandwidth"
- But instruments can quickly become complex, unstable, and difficult to learn
- It is tempting to A.I. to instruments but this can often be bad design if the player feels the instrument too obviously has a 'mind of its own'

Perry's Principles



Human/Artistic Principles

P1: Programmability is a curse

P2: Smart instruments are often not smart

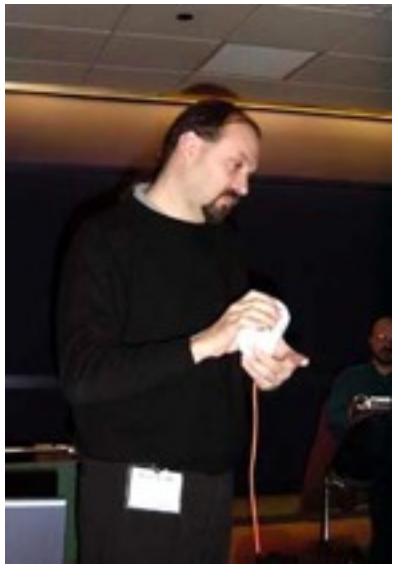
P3: Copying an instrument is dumb, leveraging expert technique is smart

P4: Some players have spare bandwidth, some do not

P5: Make a piece, not an instrument or controller

P6: Instant music, subtlety later

Perry's Principles



Human/Artistic Principles

P1: Programmability is a curse

P2: Smart instruments are often not smart

P3: Copying an instrument is dumb, leveraging expert technique is smart

P4: Some players have spare bandwidth, some do not

P5: Make a piece, not an instrument or controller

P6: Instant music, subtlety later

P5: Make a piece not a controller
P6:Instant Music, Subtlety later

- Making music is the goal
- The ideal new musical interfaces has:

  'Low entry fee with no ceiling on virtuosity'

  Wessel & Wright, NIME-01

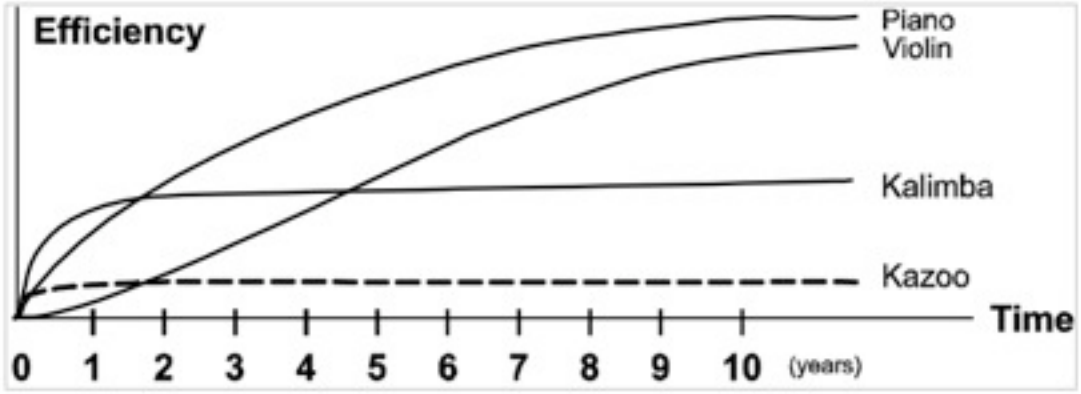
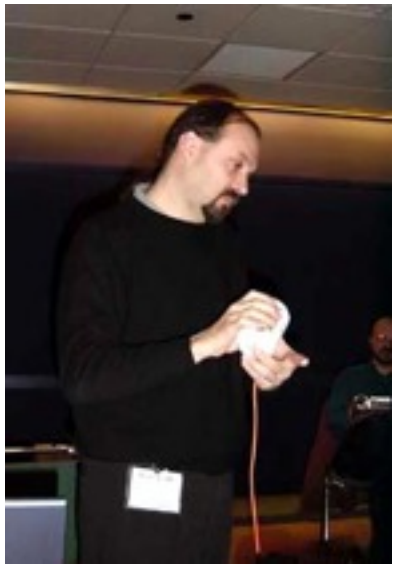


Figure 1. Approximate learning curve for the (a) kazoo, (b) kalimba, (c) piano and (d) violin, within a period of 10 years.

Jorda, NIME-04

Perry's Principles



Human/Artistic Principles

P1: Programmability is a curse

P2: Smart instruments are often not smart

P3: Copying an instrument is dumb, leveraging expert technique is smart

P4: Some players have spare bandwidth, some do not

P5: Make a piece, not an instrument or controller

P6: Instant music, subtlety later

Perry's Principles*

Technological:

P7: Miracle, Industry Designed, Inadequate

P8: Batteries, Die (a command not an observation)

P9: Wires are not that bad (compared to wireless)

Misc.:

P10: New algorithms suggest new controllers

P11: New controllers suggest new algorithms

P12: Existing Instruments suggest new controllers

P13: Everyday objects suggest amusing controllers

Perry's Principles*

Technological:

P7: Miracle, Industry Designed, Inadequate

P8: Batteries, Die (a command not an observation)

P9: Wires are not that bad (compared to wireless)

Misc.:

P10: New algorithms suggest new controllers

P11: New controllers suggest new algorithms

P12: Existing Instruments suggest new controllers

P13: Everyday objects suggest amusing controllers

P13: Everyday objects suggest controllers that are both amusing & good

- Sonic Banana *(E. Singer, NIME-03)*
- Java mug & Fillup Glass *(P. Cook, NIME-01)*

Eric Singer - Sonic Banana

Perry's Principles*

Technological:

P7: Miracle, Industry Designed, Inadequate

P8: Batteries, Die (a command not an observation)

P9: Wires are not that bad (compared to wireless)

Misc.:

P10: New algorithms suggest new controllers

P11: New controllers suggest new algorithms

P12: Existing Instruments suggest new controllers

P13: Everyday objects suggest amusing controllers

Perry's Principles*

New (as of 2007)

P14: More can be better (but hard)

P15: Music + Engineering is a great Teaching (and Marketing) tool

P17: Younger students are more fearless

Perry's Principles*

New (as of 2007)

P14: More can be better (but hard)

P15: Music + Engineering is a great Teaching (and Marketing) tool

P17: Younger students are more fearless

P15: Music + Engineering is a great Teaching Tool

- High student interest
- Motivation for learning a range of core topics including:
  - Sensors
  - HCI
  - DSP
  - Math skills
  - Programming
  - Networking

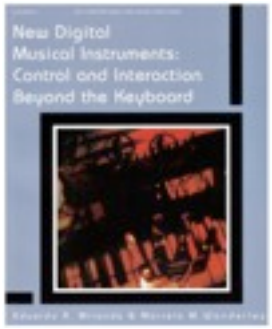
Joe Paradiso & student (NIME-02)

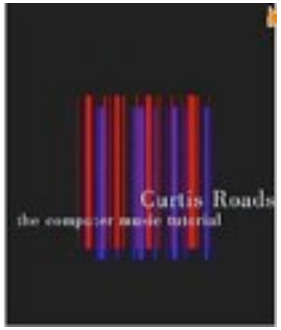
Where to study this field?

- IRCAM, Paris
- CCRMA, Stanford
- CIRMMT, McGill
- Princeton, CS & Music
- NYU Interactive Telecommunications Program
- SARC, Queen's, Belfast
- Growing field …
- URLs listed in the References

Specific Learning Resources

- Miranda & Wanderley (2006)
- Igoe (2007)
- Roads (1996)
- NIME Proceedings
- ICMC Proceedings
- Computer Music Journal
- Organized Sound
- J. New Music Research





Summary

- Technology is increasing the fluidity of musical culture
- NIME presents special challenges for performers
- Well-designed visual feedback can greatly improve mapping transparency for audience and player
- Interaction metaphors another strategy
- Initial failure can enhance eventual success
- Perry's principles provide practical policies

Questions/Discussion

Break

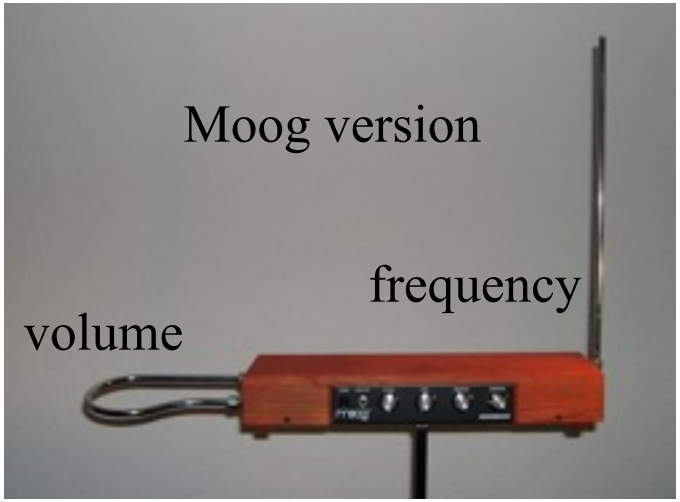
Start again at 3:30!

Module 4: NIME after NIME

photo: Lydia Kavina

Original NIMEs

- Leon Theremin, 1928
  - senses hand position relative to antennae
    - controls frequency and amplitude
  - Clara Rockmore playing

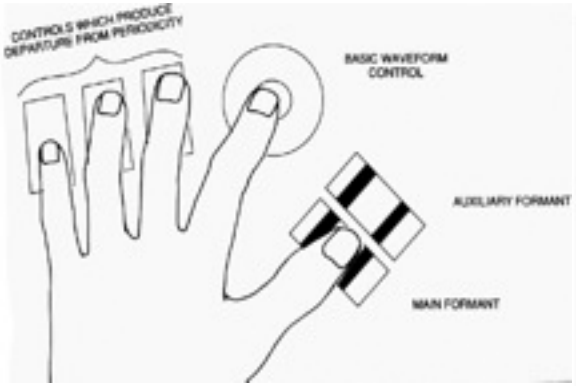


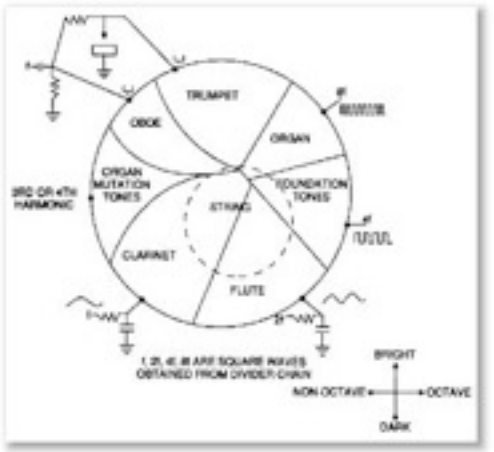
More original NIMEs

- Hugh Le Caine (1940s)
  - electronic sackbut
  - sensor keyboard
    - downward and side-to-side
    - potentiometers
  - right hand can modulate loudness and pitch
  - left hand modulates waveform
    - precursor to the mod-wheel

Science Dimension volume 9 issue 6 1977

Canada Science and Technology Museum



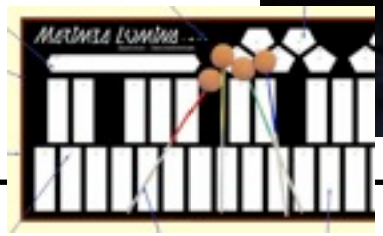


Buchla's Midi Controllers

- Thunder (1990)
  - 36 touch sensors

- Lightning 2 (1996)
  - LED based position sensing

- Marimba Lumina (1999)
  - pads and ribbon controllers (strips)
  - bars are sensitive to proximity, hit location and movement
  - 4 different mallets for different effects



There's a lot of NIMEs out there

	2001	2002	2003	2004	2005	2006	2007	2008	Total
Instrument-like	1	2	2	2	2	4	4	1	18
Instrument-inspired	2	4	1	1	-	3	2	1	14
Extended instrument	2	4	5	3	5	7	6	5	37
Alternate controllers	21	31	24	23	35	22	19	22	197
Total	26	41	32	29	42	36	31	29	266

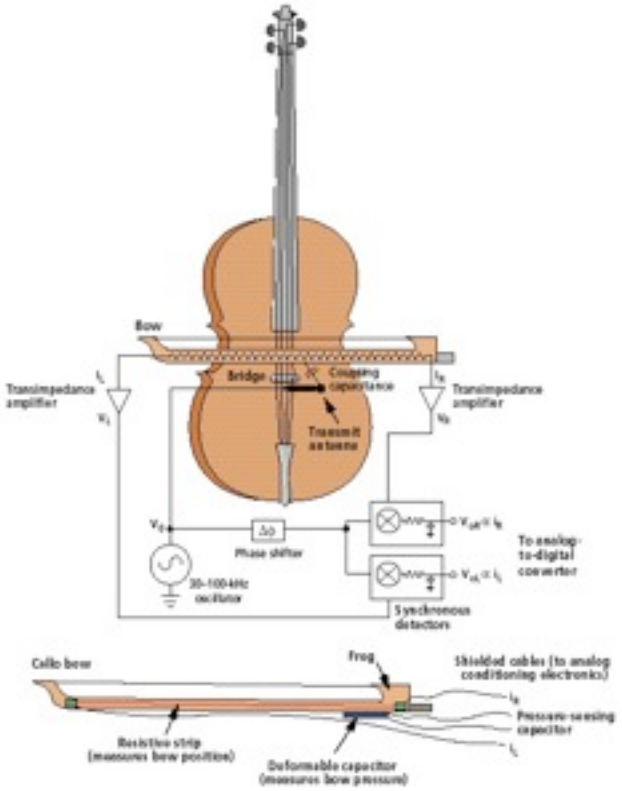
Table 3.2: Classes of instruments presented at the NIME conferences, by year

(Marshall, 2009)

- Most are classed in the "Alternate" category

Augmented Instruments

- Hypercello *(Gershenfeld & Chung, 1991)*
  - related Hyperbow *(Young, 2001)*



Yo-Yo Ma, Tanglewood on August 14, 1991

Alternative Instruments: Using different sensors

Sensor	Occurences	Property Sensed
FSR	68	Force
Accelerometer	56	Acceleration
Video Camera	54	
Button/Switch	51	Position (On/Off)
Rotary Potentiometer	31	Rotary Position
Microphone	29	Sound Pressure
Linear Potentiometer	28	Linear Position
Infrared Distance Sensor	27	Linear Position
Linear Position Sensor	23	Linear Position
Bend Sensor	21	Rotary Position (Bending)

Table 3.3: Most popular sensors from NIME instruments

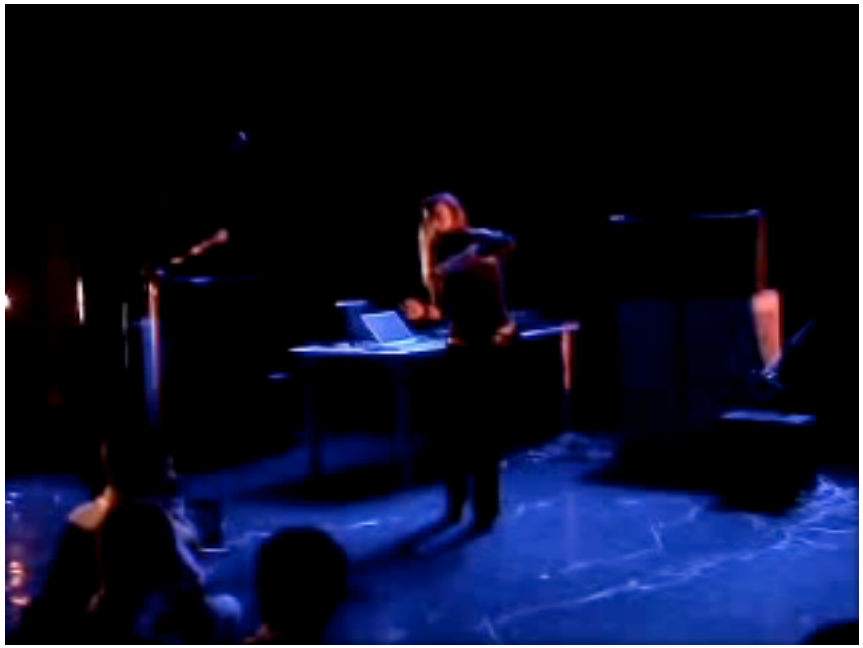
(Marshall, 2009)

Alternative Instruments

- approaches to taxonomy:
  - sensed property (i.e. wind)
  - player action (i.e. percussion)
  - instrument shape
  - relationship to body

Hands Only - free gesture + physical

- Lady's Glove *(Sonami, 1991+)*
  - hall effect sensors, microswitches, resistive strips, pressure pad, accelerometer
  - controlled musical effects



Hand - Contact gesture

- Lippold Haken's Continuum
  - touch sensitive - neoprene covered
    - x, y along board
    - z - pressure
  - MIDI controller
    - sound effects
    - continuous frequency
    - pitch bends

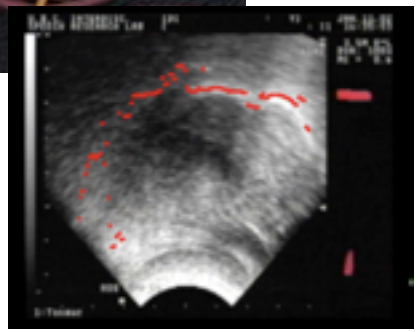
Jordan Rudess (Dream Theater), 2005

Breath and Hands

- iPhone Ocarina *(Wang, 2009)*
  - touch screen plus microphone
  - mapped to tones for ocarina sounds

Face/Head Control

- eSitar *(Kapur et al, 2004)*
  - accelerometer for head tilt
    - experimented with volume, duration, and more
- Mouthesizer (Lyons et al., 2003)
- SoFA, (Funk et al., 2005)
- Tongue'n Groove (Vogt et al., 2002)
  - ultrasound probe to measure tongue movement



Body

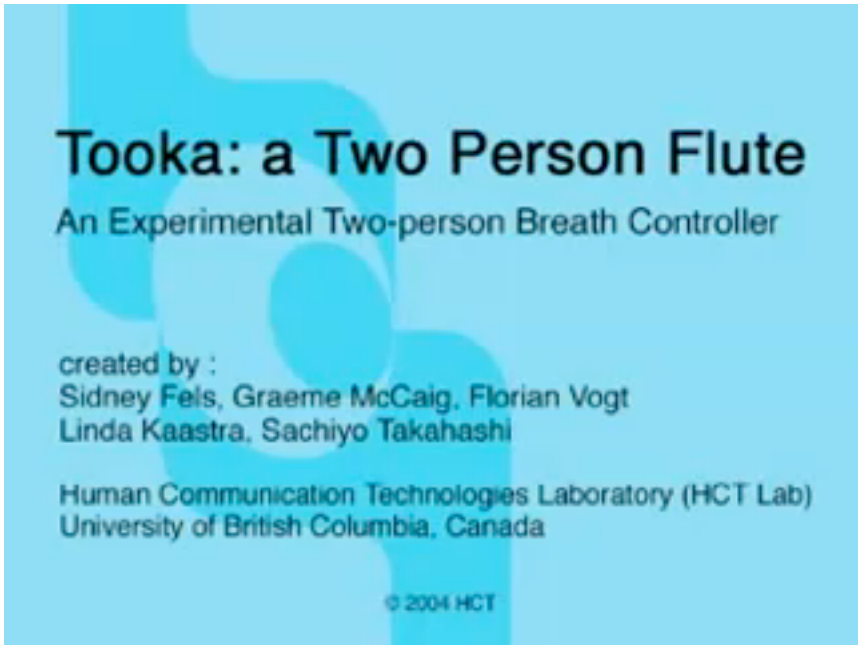
- Miburi from Yamaha, 1994
  - bend sensors at arm joints
  - two buttons/finger and thumb
  - two pressure sensors/foot
  - MIDI controller

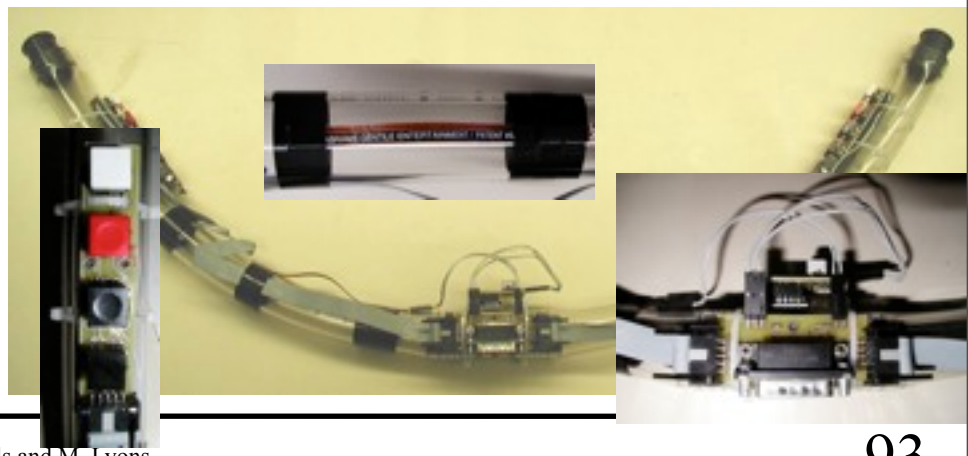
Inside Body

- Biomuse *(Knapp and Lusted, 1990)*
  - 8 channel signal amp
    - EMG, EKG, EOG, EEG
- Tibeten singing bowls *(Tanaka and Knapp, 2002)*
  - EMG and position sensing
- miniBioMuseIII *(Nagashima, 2003)*
  - 8 EMG channels
    - mapped to bandpass filters, sinewave generators and FM synthesizers
  - used in BioCosmicStorm-II

Collaborative Instruments

- Tooka *(Fels and Vogt, 2002)*
  - pressure for breath
  - buttons for fingers
  - bend sensor
  - touch sensor
- two players share breath
- coordinate movements
- MIDI mapping





NIMEs for Novices:
Jam-o-drum *(Blaine and Perkis, 2000)*

- 4 player audio/visual interface
  - drum pads sensors with rotation sensor around rim
- Drum circle concept
- Various musical games
  - turn taking
  - collaboration

NIMEs for Novices

- **Interactive instruments embody all of the nuance, power, and potential of deterministic instruments, but the way they function allows for anyone, from the most skilled and musically talented performers to the most unskilled members of the large public, to participate in a musical process** ***(Chadabe, 2002)***

- Walk up and play

NIMEs for Novices

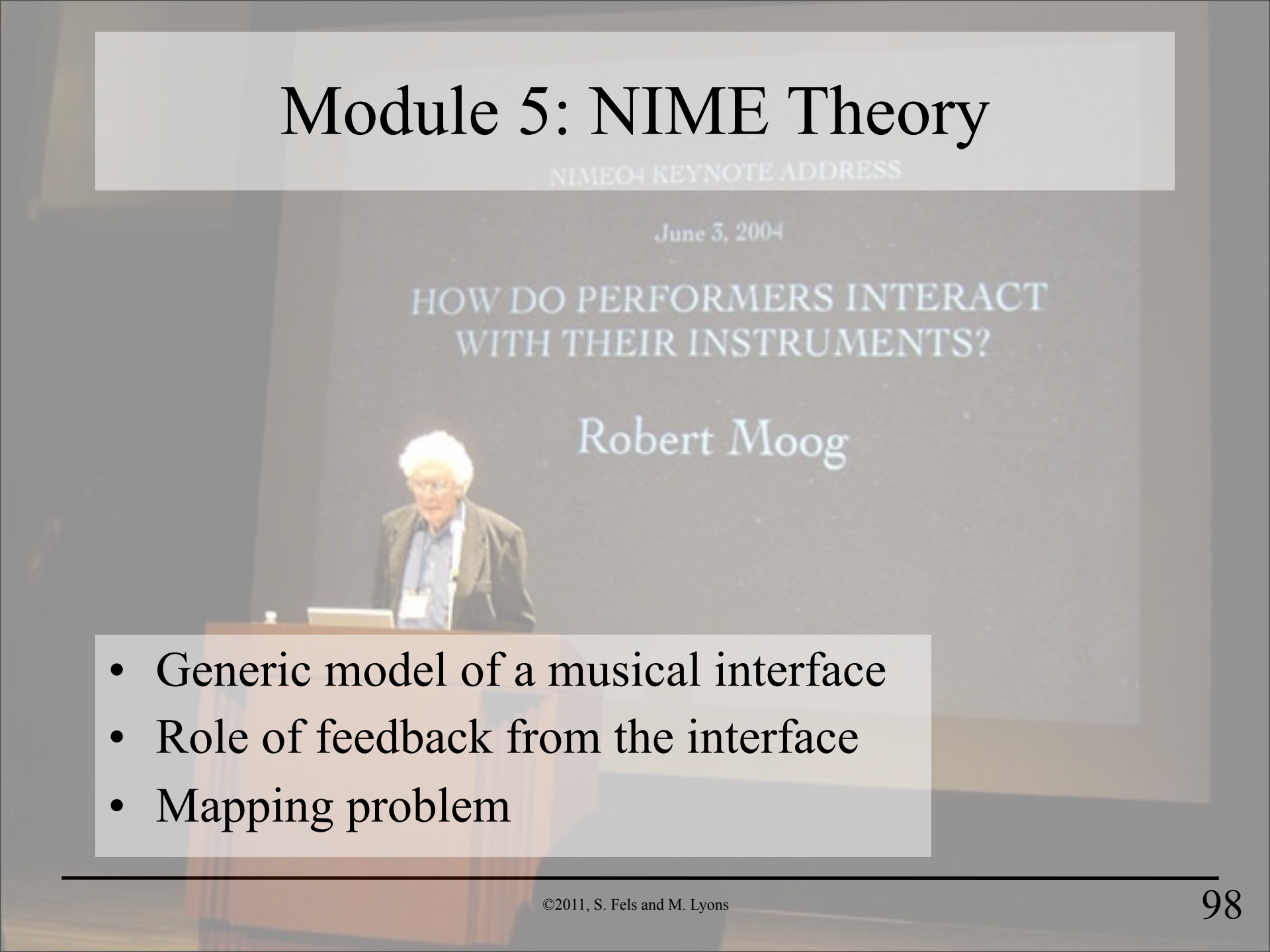
(Blaine & Fels, 2003)

			Aptitude	
			Novice	Virtuoso
Capacity	Single player	Single interface	Electronic Bullroarer Iamascope	Duet on piano
		Multiple interfaces	Musical Trinkets	Jazz Ensembles
	Multiple players	Single interface	Beatbugs Squeezables Audio Grove Sound Mapping Speaking Orbs Jamodrum	Mikrophonie I, Tooka
		Multiple interfaces	Augmented Groove Brain Opera Drum Circle	Mikrophonie II

Summary

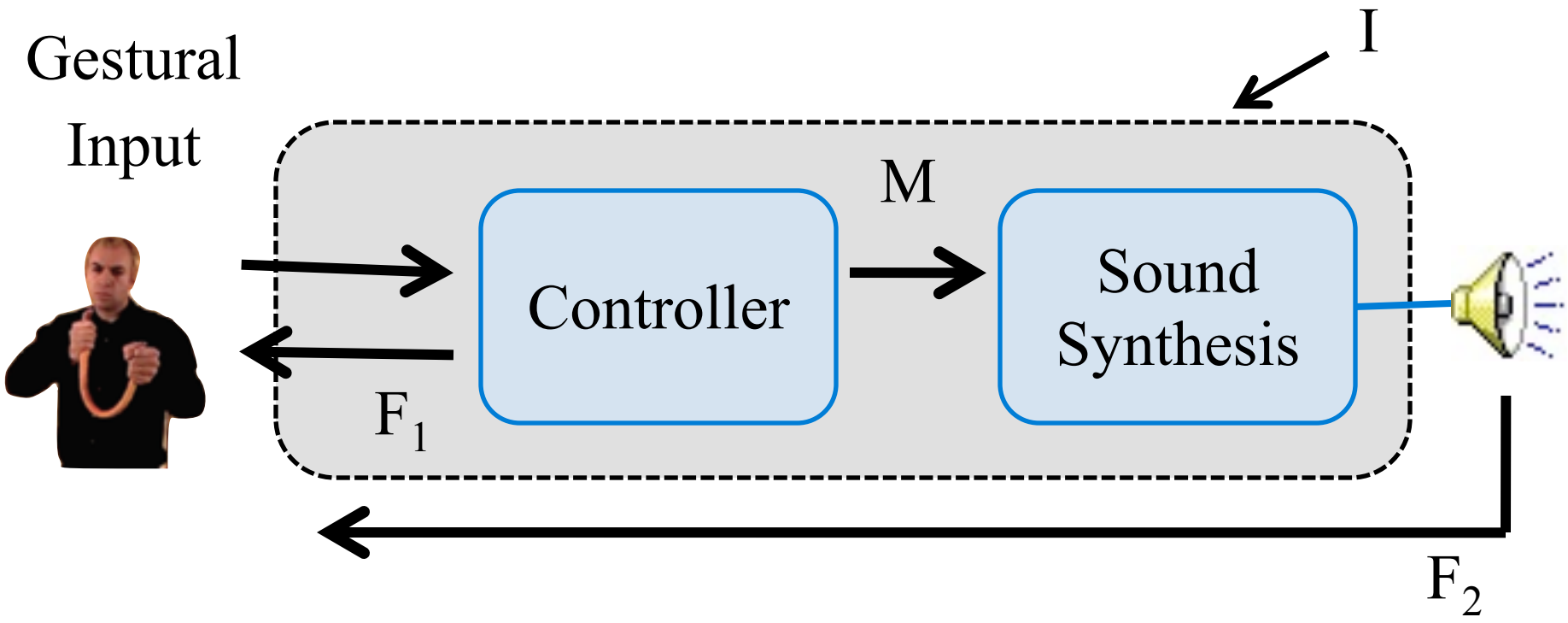
- Creating a NIME is easy to do
- Creating a good mapping is hard
- Playing it well takes practice to be a virtuoso
  - some NIMEs created to be easy to play but not so expressive
- Without a piece, difficult to gain acceptance
- Often audience doesn't know what is going on
- Many explorations trying different ways to make music

Module 5: NIME Theory



- Generic model of a musical interface
- Role of feedback from the interface
- Mapping problem

NIME – Generic Model



M : Mapping,

F_1, F_2 : Primary & Secondary Feedback

Based on: Miranda & Wanderley (2006)

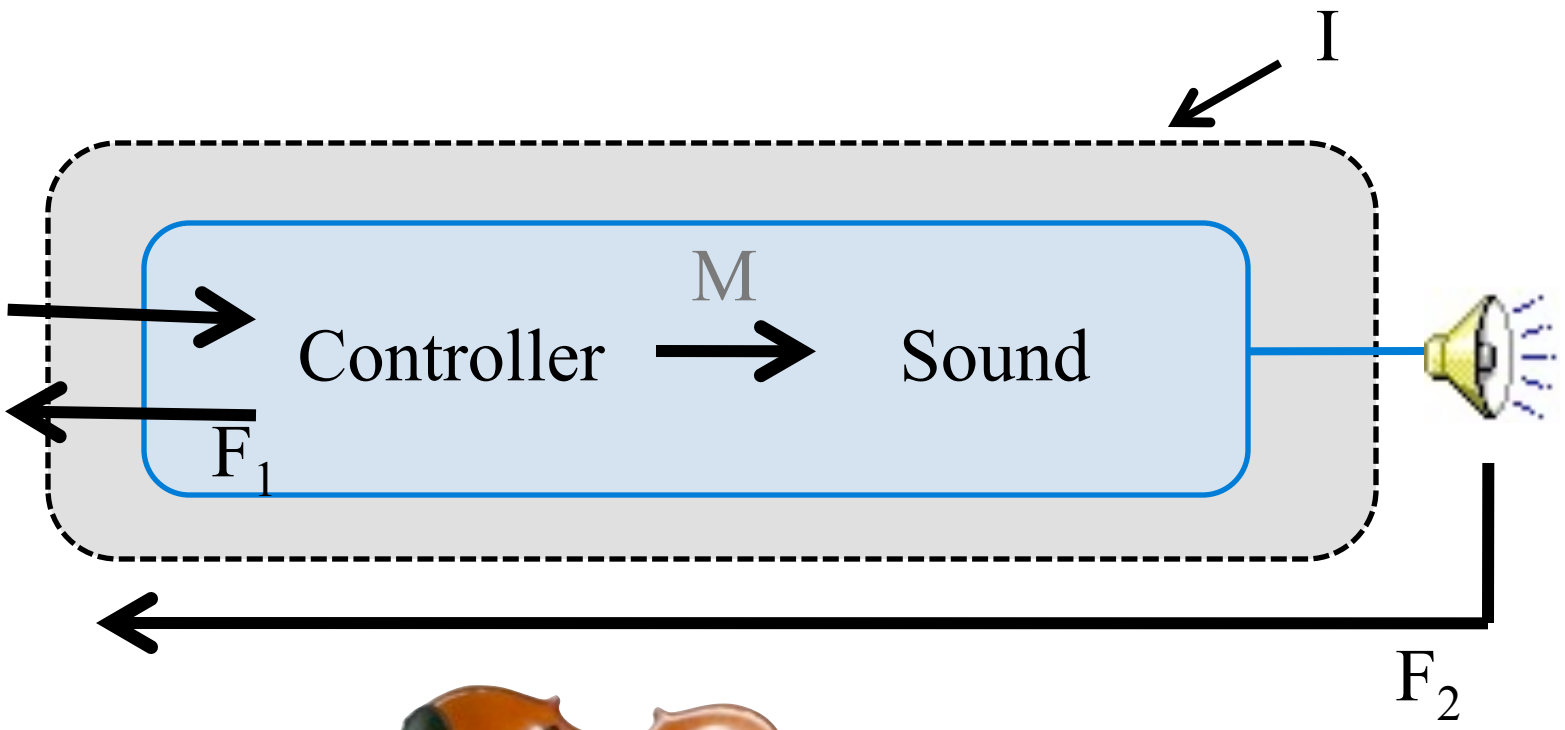
Feedback Design: F1 and F2

- Sound } F_2

- Tactile*
- Kinesthetic
- Visual** } F_1

- *Includes vibro-tactile feedback due to sound waves on the instrument
- ** Re: Module 2 on Visual Interfaces

Model: 'Traditional' Instrument



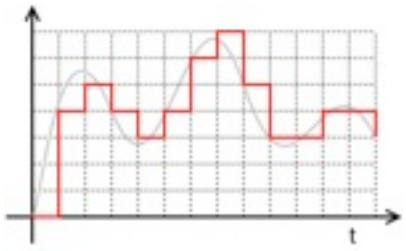
Gestural Input

NIMEs decouple

- Control separate from Synthesis
- Mapping (M) is designed
- Feedback (F1 and F2) is designed
- Controller/Interface is designed

NIME representations

- discrete vs. continuous controllers
  - keys vs knobs
- acoustic vs electronic sound output
  - vibrating string vs. speaker
- digital vs analog representations
  - bits vs. voltage



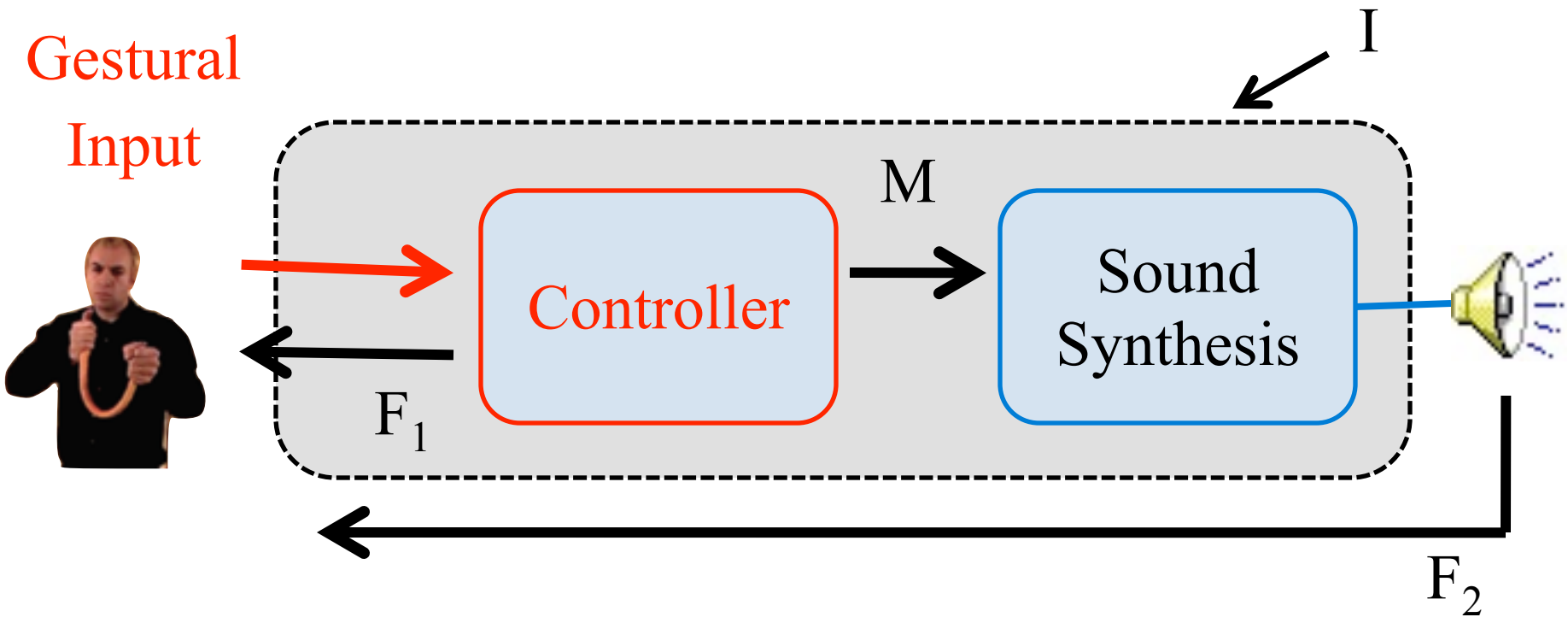
NIME, DMI, Instrument

- **musical interface** and **nime** used interchangeably
- DMI – ‘Digital Musical Instrument’
- DMI & MI may be preferable because a NIME will not be new forever

Digital NIME

- Computer enables arbitrary design of interface behaviour:
  - controller
  - feedback (F1 & F2)
  - mapping (M)
  - synthesizer

NIME – Generic Model



M : Mapping,

F_1, F_2 : Primary & Secondary Feedback

Based on: Miranda & Wanderley (2006)

Designing Controllers: Gestural Input

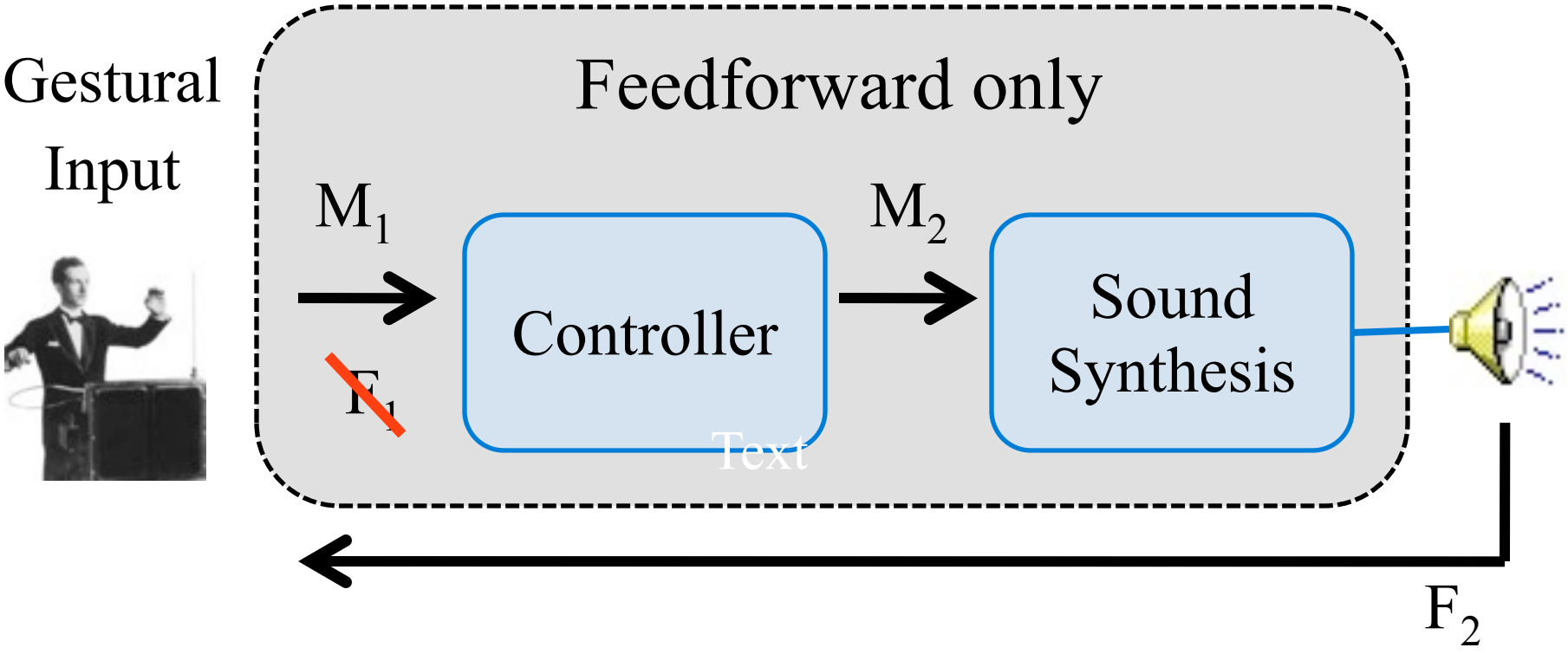
- Free gesture interfaces
  - no physical contact
- Physical contact interfaces
  - all acoustic instruments
- NIMEs can be in either

Free Gesture Interface

- Theremin (1919)
- Sound feedback (F_2) only
- No primary tactile or visual feedback (F_1)

- Have been few virtuosos
- Considered difficult to master

Léon Theremin



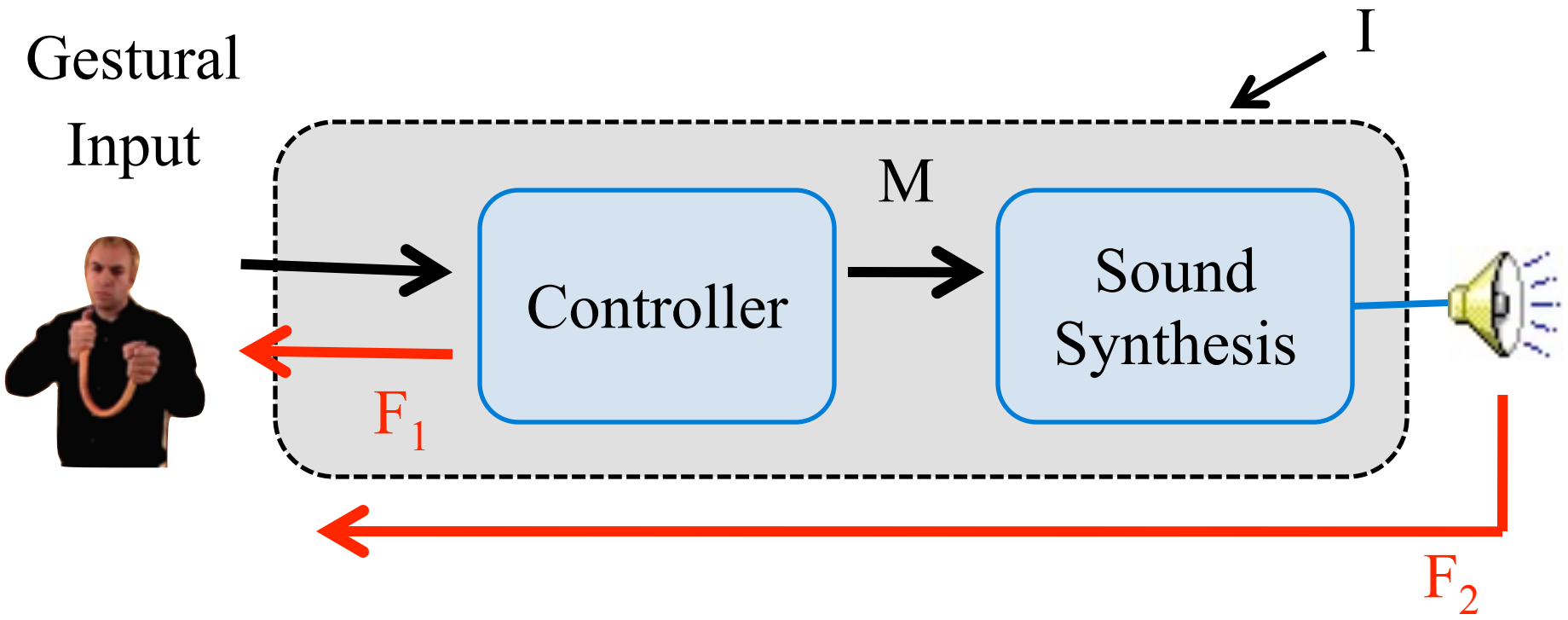
Theremin lacks significant primary feedback

The Hands

- Passive F_1

Michel Waisvisz *et al.*
STEIM, Amsterdam
(Studio for Electro-instrumental Music)

NIME – Generic Model



M : Mapping,

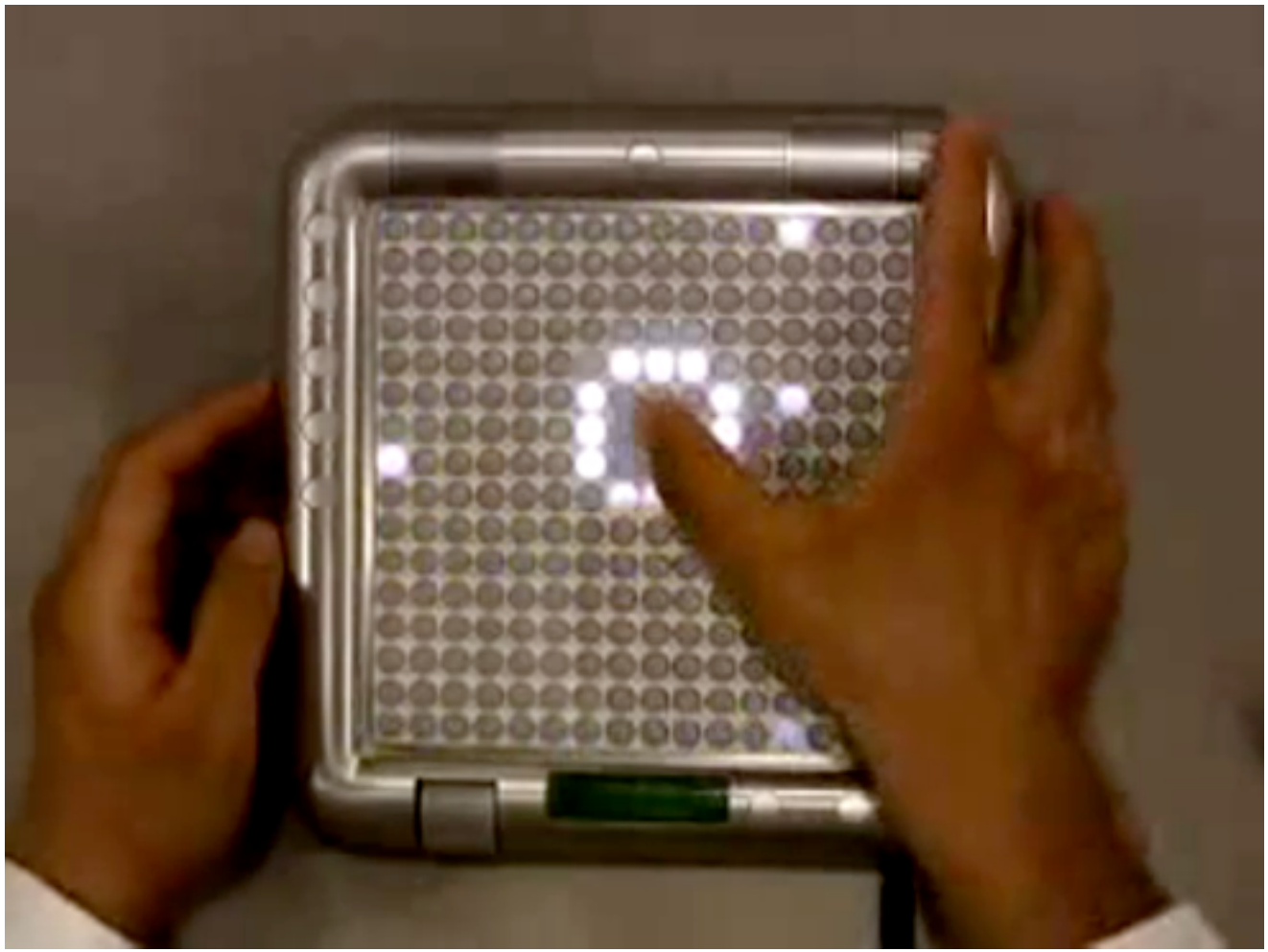
F_1, F_2 : Primary & Secondary Feedback

Based on: Miranda & Wanderley (2006)

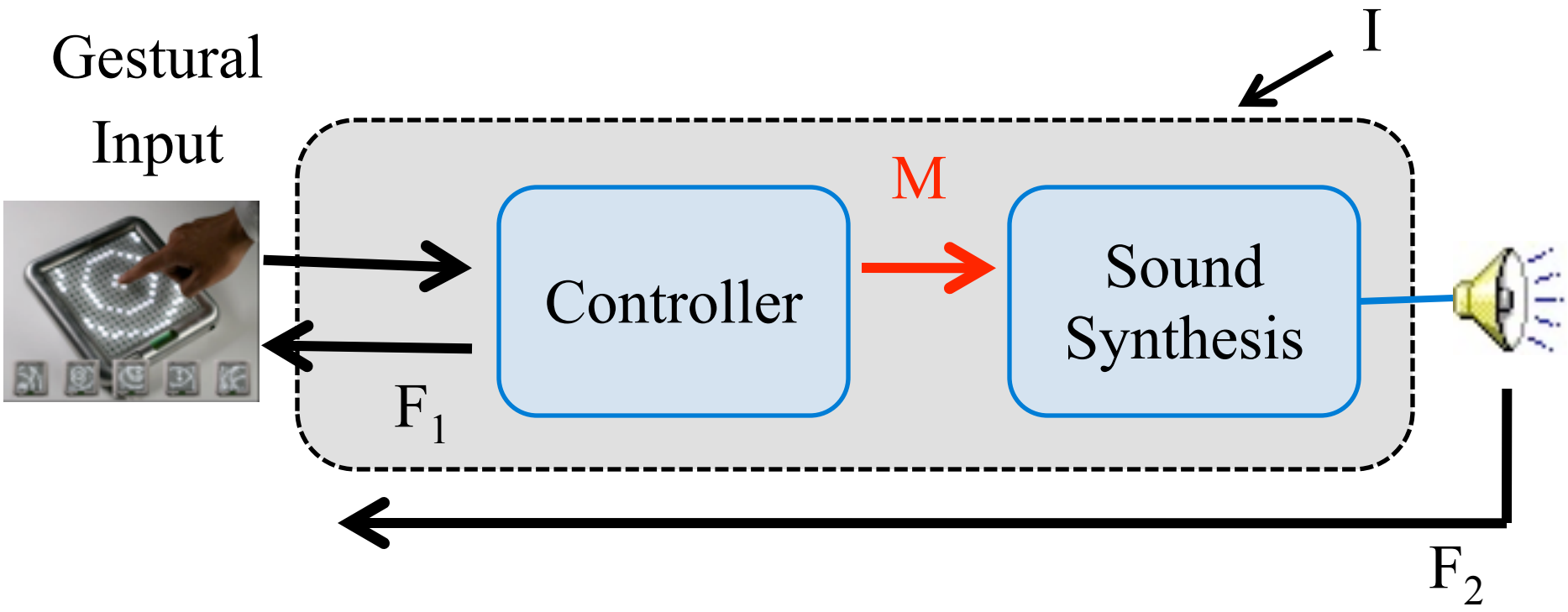
F_1 : Visual & Tactile Feedback

Nishiburi & Iwai NIME-06

Tenori-on



NIME – Generic Model



M : Mapping,

F_1, F_2 : Primary & Secondary Feedback

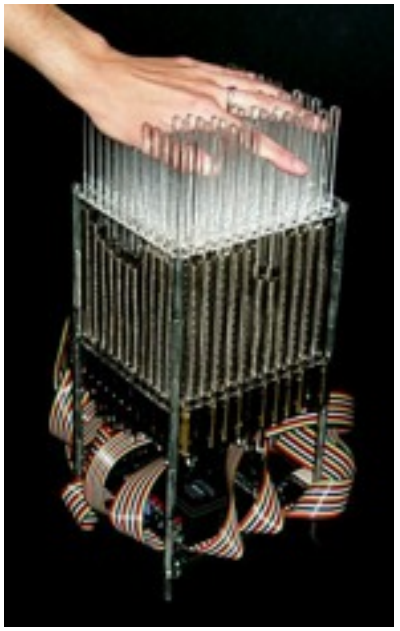
Based on: Miranda & Wanderley (2006)

Instrument Mapping

Shakuhachi

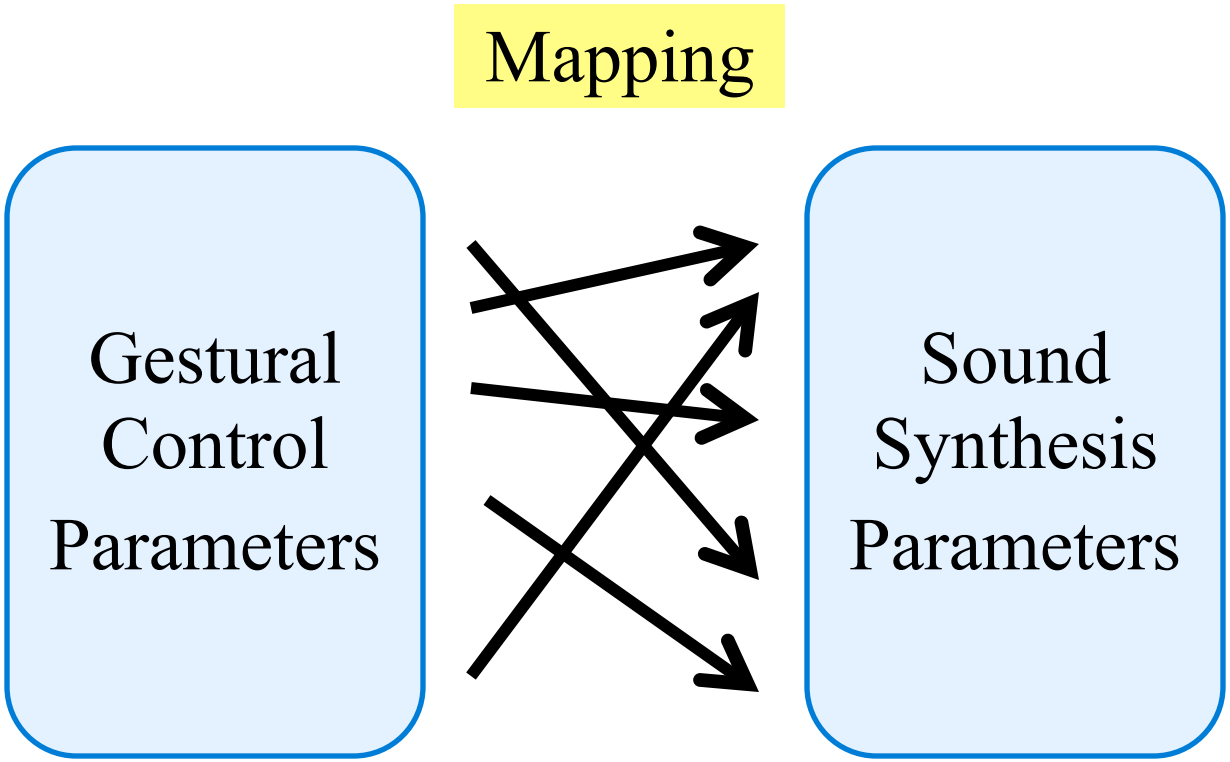
Fairlight CMI, 1980s T. Kriese

Polyphonic Digital Sampling Synth



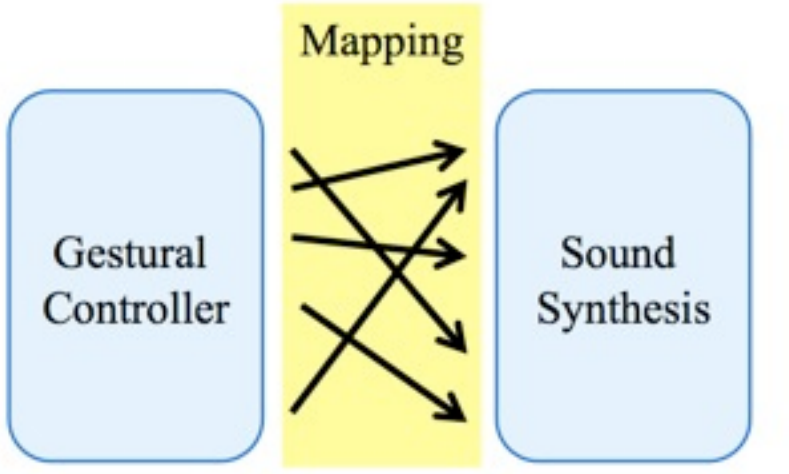
Matrix
(Overholt, 2001)

‘Mapping Problem’:
How to design the gesture to sound mapping?



Aspects of the Mapping Problem

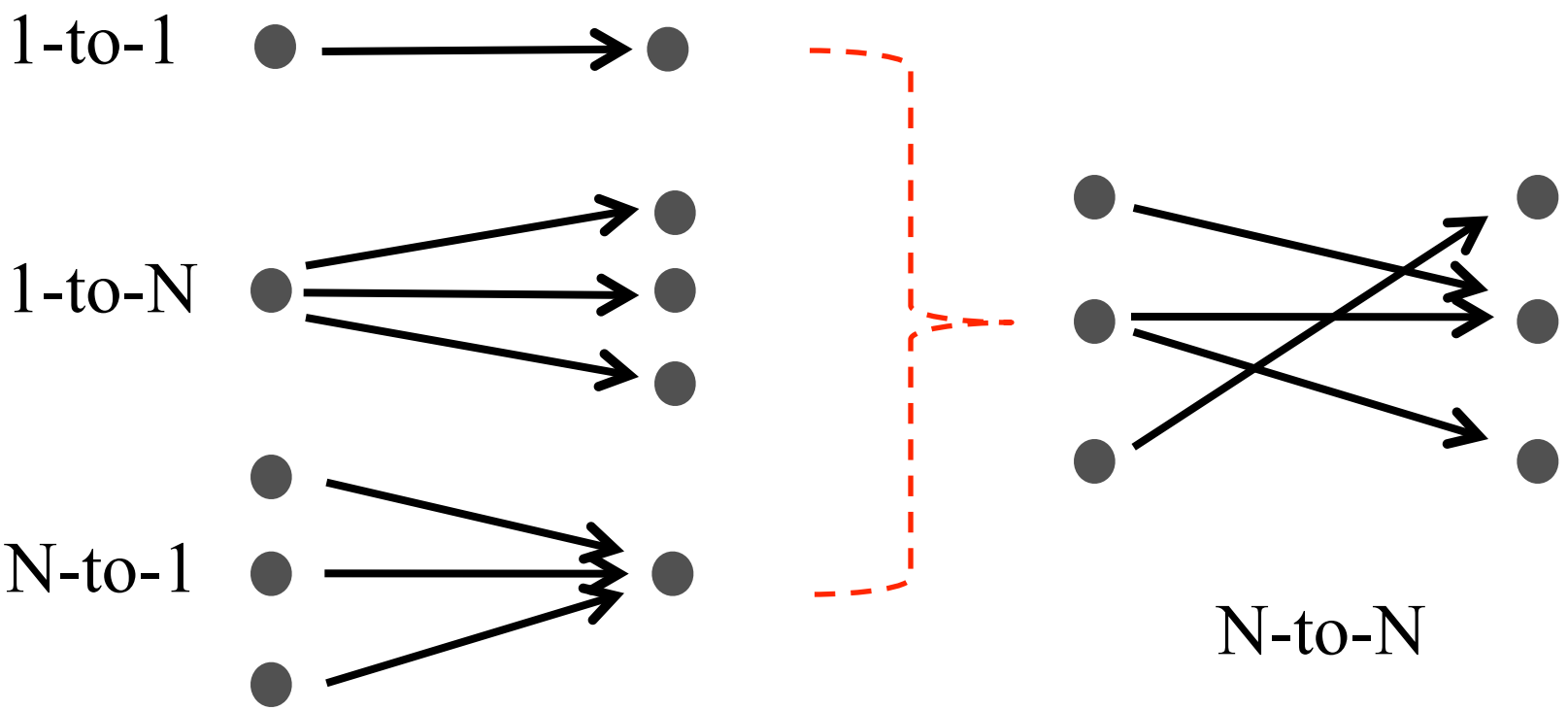
- Dimensionality
- Complexity
- Mapping Strategy
- Other aspects …



The mapping layer can be considered as the essence of a musical interface

Hunt, Wanderley, and Paradis (2003)

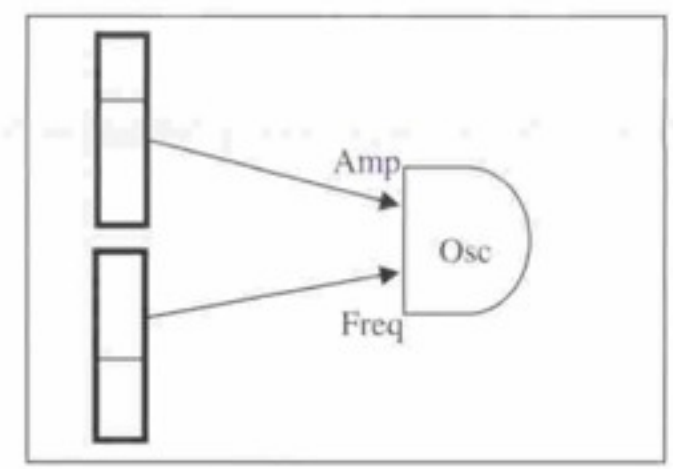
Dimensionality: Types of Mapping



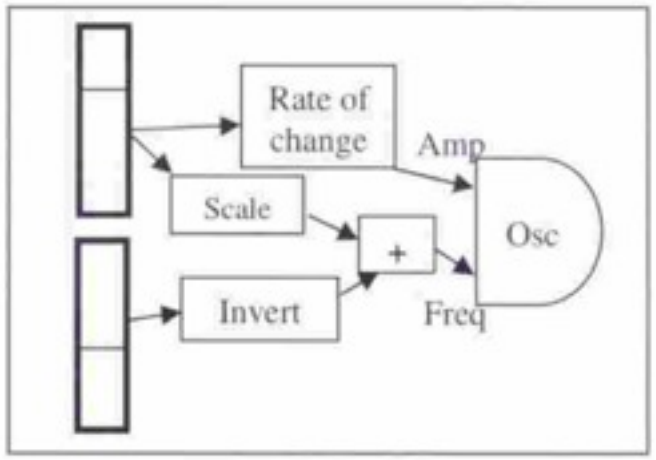
Gestural Parameters

Synthesis Parameters

Complexity: Simple & Complex Mappings



Simple



Complex

Hunt, Wanderley, and Paradis (2003)

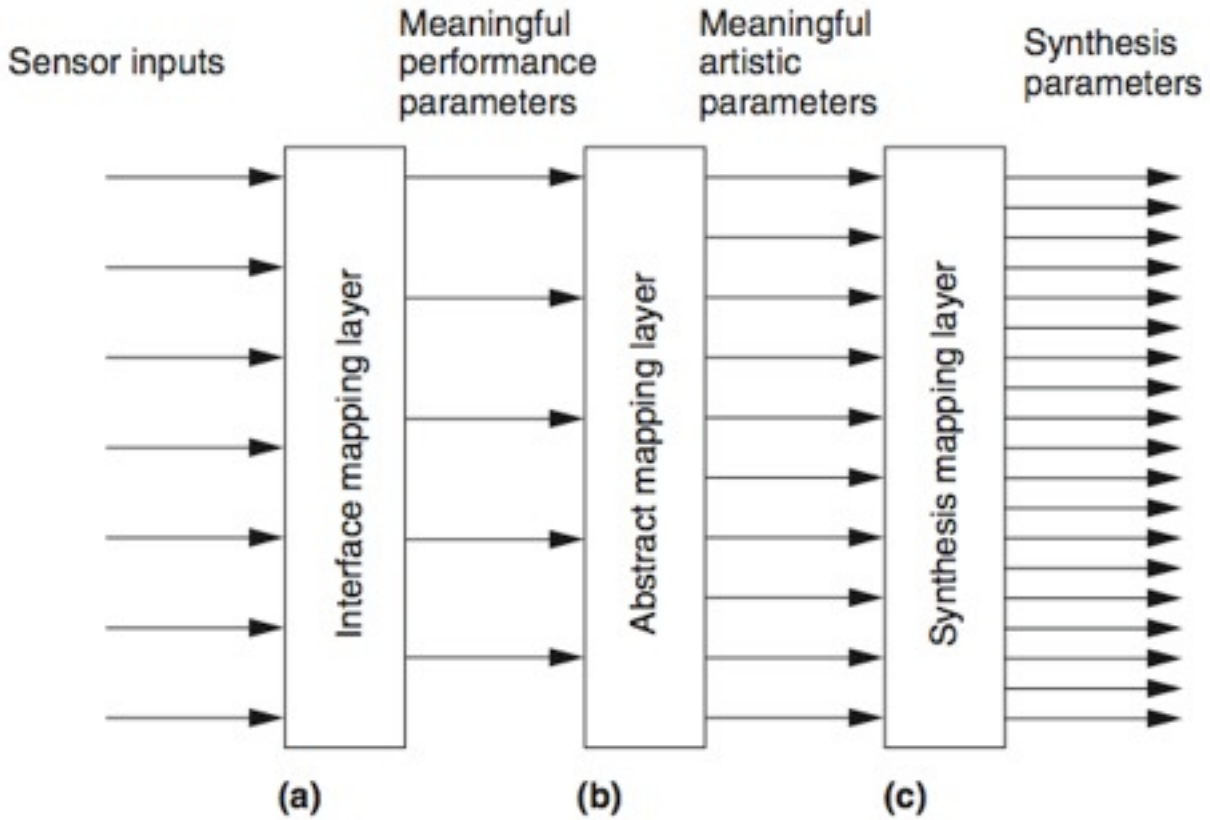
Mapping Complexity

complexity can lead to better expression

- 1 to 1 usually doesn't do the trick
    * not interesting
    * not enjoyable
    * not satisfying

Hunt, Wanderley, & Paradis, NIME-02

Understanding Complexity: Three Layer Mapping Strategy



Hunt, Kirk, and Neighbour (2004)

Abstract Mapping Layer example

Mouthesizer interface (Module 2: Camera-based Interfaces)

Controlling a Formant Filter using Mouth Shape

[o]

[a]

[i]

Lyons et al., NIME-03

Mouthesizer Vowel Mapping

Mapping Design Strategy

- Advantage to have a control interface which is based on the **perceptual qualities** of timbre spaces
- Better mapping leads to more playable interface

- How do we characterize playability?

Musical Control Intimacy

"... the match between the variety of musically desirable sounds produced and the psycho-physiological capabilities of a practiced performer."

Moore (1988)

Control Intimacy depends (somehow) upon **gesture to sound mapping**

Flow in musical expression

- Special contact with the instrument
- Development of a subtle feeling for sound
- Feeling of effortlessness
- Playful & Free-spirited feeling handling of the material
- *A. Burzick (2002)*

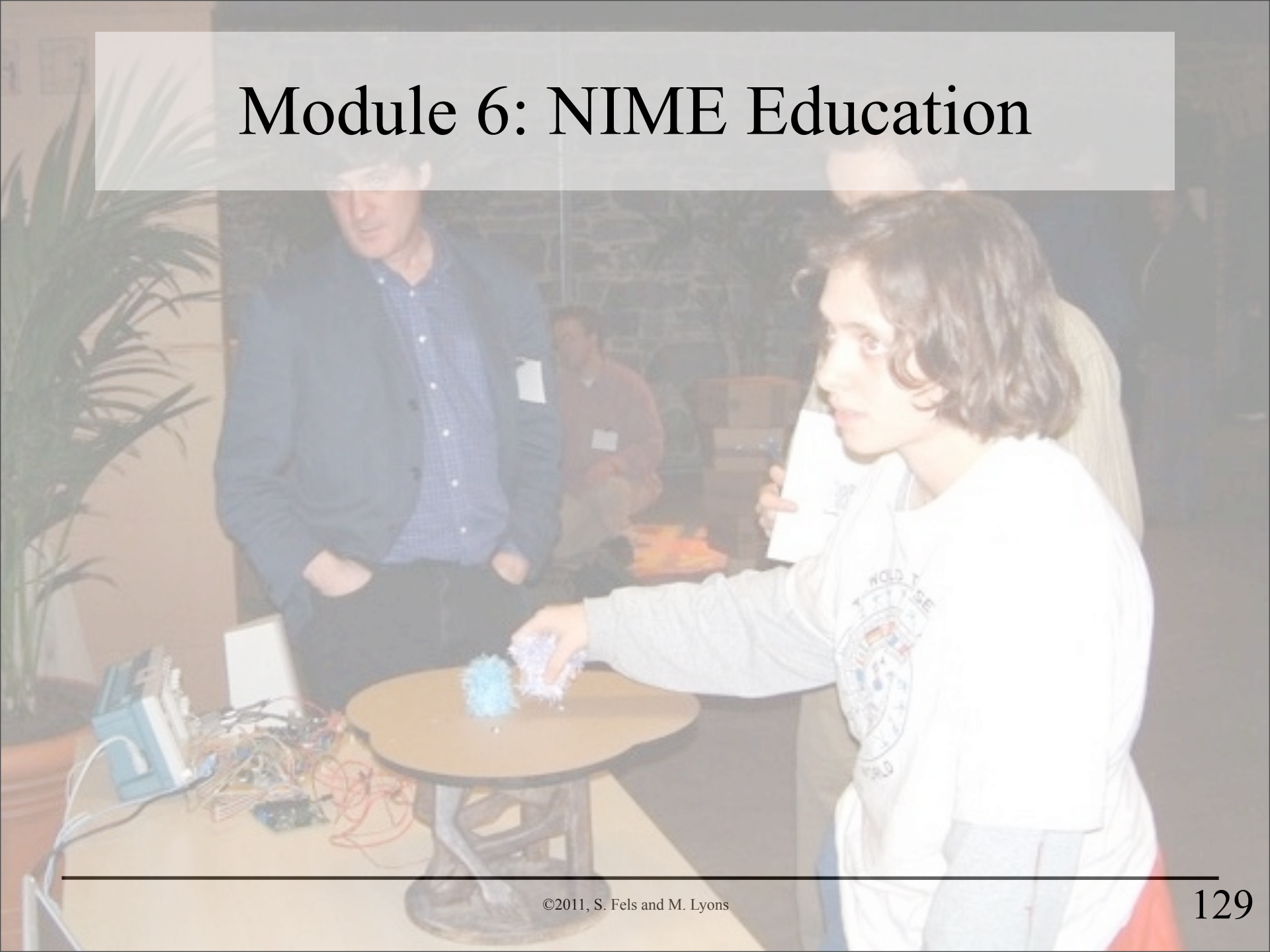
Threats to Intimacy

- Latency between gesture and sound
- Lack of primary feedback
- Poor mapping

Summary

- Generic musical interface model is helpful in understanding what makes & breaks a NIME
- Mapping constitutes the essence of a digital NIME
- Mapping is not straightforward and many design ‘strategies’ have been tried
- Multiplayer mappings can be better than simple one-to-one mappings
- Studies of mapping and feedback are core research topics of NIME

Module 6: NIME Education



Education and NIME

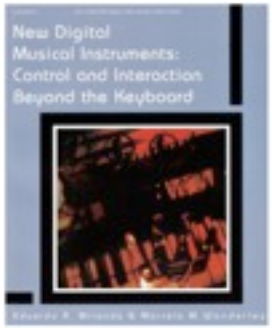
- Sound Synthesis
- Sensors, Effectors, Microcontrollers
- Basic Electronics
- Communication Protocols (MIDI, OSC, TCP etc.)
- Sound Synthesis and Processing
- Acoustics
- Human-Computer Interaction
- Music

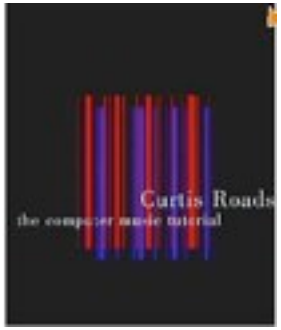
Where to study this field?

- IRCAM, Paris
- CCRMA, Stanford
- CIRMMT, McGill
- Princeton, CS & Music
- NYU Interactive Telecommunications Program
- SARC, Queen's, Belfast
- Growing field …
- URLs listed in the References

Specific Learning Resources

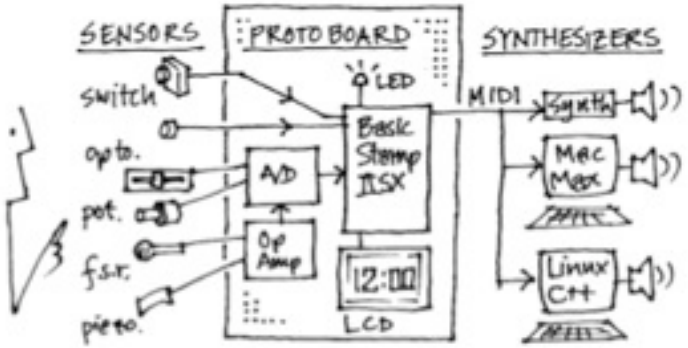
- Miranda & Wanderley (2006)
- Igoe (2007)
- Roads (1996)
- NIME Proceedings
- ICMC Proceedings
- Computer Music Journal
- Organized Sound
- J. New Music Research

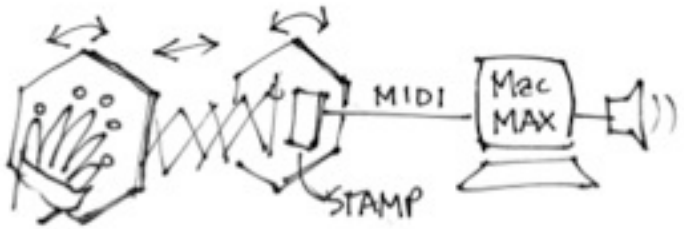




Curricula

- beginning graduate or senior undergraduate level
- Courses tend to be project oriented
- Students learn what they need
- Live performance or Demo is necessary for completion of the course (ITP, CCRMA)





Verplank, Sapp, Matthews (NIME-01)

New Interfaces for Musical Expression

interactive telecommunications program

- NYU ITP NIME Course
- Master's program in design & technology attracting students from a wide range of backgrounds

Gideon D'Arcangelo

Hans C. Steiner

Jamie Allen

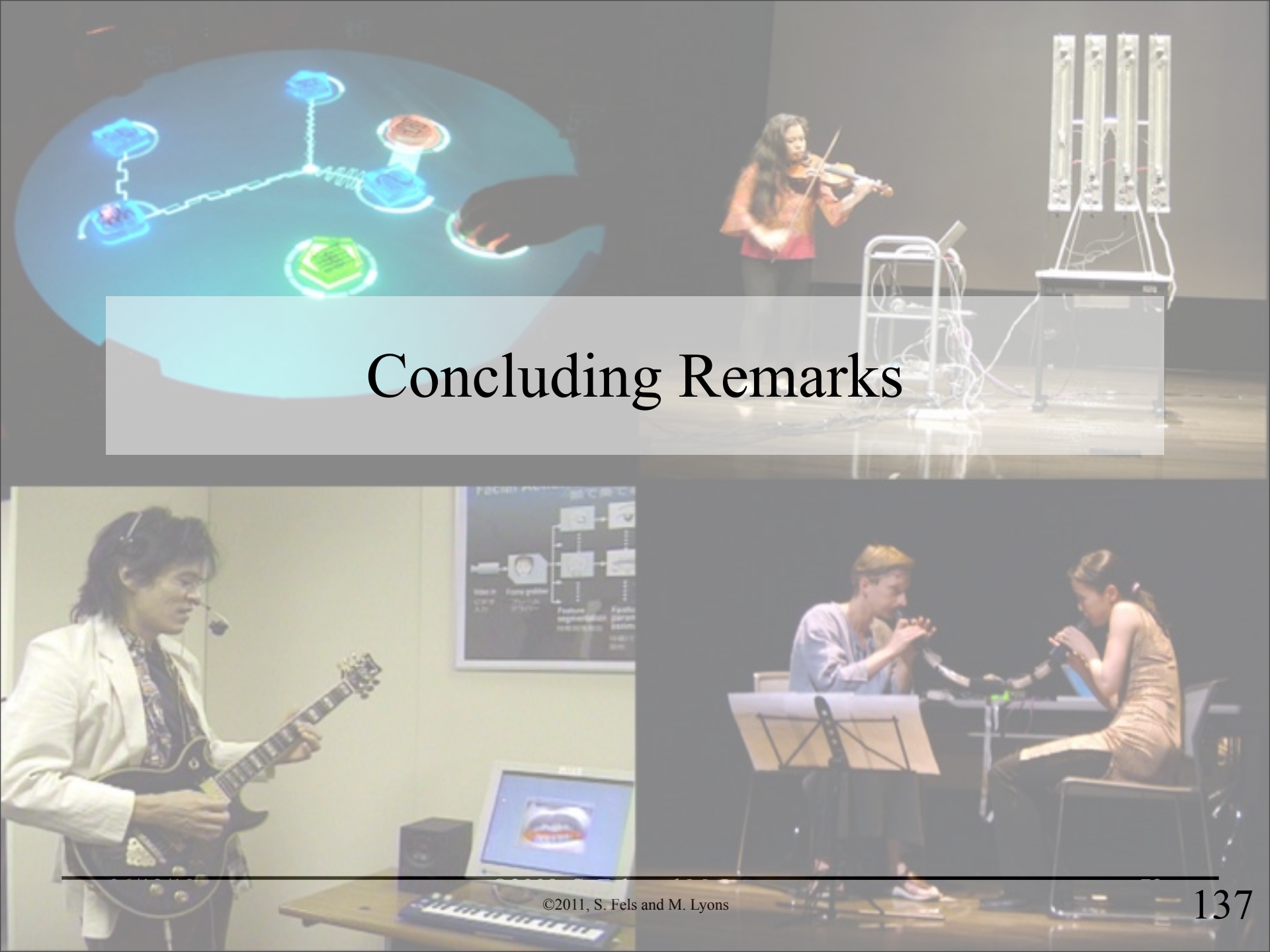
Taku Lippit (NIME-04)

NIME Curriculum - Topics

- Historical Survey of Musical Instrument Types
- Attributes of Musical Expression
- Music Theory and Composition
- Musical Interface Responsiveness
- Discrete vs. Continuous Controllers
- Gestures and Mapping
- Novice and Expert Interfaces
- Spectacle and Visual Feedback in Performance
- Collaborative Interfaces

Summary

- Substantial resources for learning about NIME
- NIME courses are usually project based
- Number of universities offering programs of study is expanding
- Next frontier: high schools, science fairs



Concluding Remarks

How to Play the Computer?

- Computers offer a wide range of sound and music creation opportunities
- How can we create new interfaces to play computers in a way that is appropriate to human brains & bodies?

Here's how…

- NIME tools
- NIME principles
- NIME examples
- NIME theory
- NIME education

How to get involved

- NIME community
  - community@nime.org
    - subscribe with community-request@nime.org
- NIME website
  - www.nime.org
- ICMC website
  - www.computermusic.org/
- Related conferences

Bigger picture

1. introduced the theory and practice of NIME
2. NIME community is very accessible and growing
3. get to know some of the people of NIME
4. easy to start creating NIMEs and a lifetime of enjoyment to master
5. musical expression transcends gender and culture
6. if you are not having fun, it's probably not for you

Questions & Discussions

- Contact us:
  - Sidney Fels, ssfels@ece.ubc.ca
  - Michael Lyons, lyons@im.ritsumei.ac.jp

www.nime.org

References and Resource Material

Theory

[Poupyrev et al. 2001] New interfaces for musical expression. Extended Abstracts, CHI-2001, ACM Conference on Human Factors in Computing Systems, pp. 309-310.

[Wanderley & Battier, 2000] Wanderley, M. and Battier, M. 2000. Trends in gestural control of music, IRCAM.

[Miranda & Wanderley, 2006] Miranda, E.R. and Wanderley, M.M. 2006. New digital musical instruments: control and interaction beyond the keyboard. AR Editions.

[Wessel & Wright, 2002] Problems and prospects for intimate musical control of computers, Computer Music Journal 26(3): 11—22.

[Wessel & Wright, 2001] Problems and prospects for intimate musical control of computers, In Proceedings of the 2001 Conference on New interfaces For Musical Expression (NIME-01) (Seattle, Washington, April 01 - 02, 2001).

[Vertegaal et al. 1996] Vertegaal, R. and Ungvary, T. and Kieslinger, M.1996. Towards a musician's cockpit: Transducers, feedback and musical function, Proceedings of the International Computer Music Conference, pp. 308—311.

[Mulder, 2000] Mulder, A. 2000. Towards a choice of gestural constraints for instrumental performers. In: Trends in gestural control of music, Wanderley, M. and Battier, M., eds., IRCAM.

[Camurri, 2000] Camurri, A. and Hashimoto, S. and Ricchetti, M. and Ricci, A. and Suzuki, K. and Trocca, R. and Volpe, G. 2000. EyesWeb: Toward gesture and affect recognition in interactive dance and music systems,
Computer Music Journal 24(1): 57-69.

[Waiswicz, 1985] Waiswicz, M. 1985. THE HANDS: A Set of Remote MIDI Controllers. Proceedings of the 1985 International Computer Music Conference (ICMC'85) Vancouver Canada, pp 313 – 318, San Francisco: ICMA.

[Marshall, 2009] Marshall, M.T. 2009. Physical Interface Design for Digital Musical Instruments, Ph.D. thesis, McGill University, March.
http://www.idmil.org/_media/publications/marshall_phdthesis_final.pdf

[Moore, 1988] Moore, F.R. 1988. The dysfunctions of MIDI,
Computer Music Journal 12(1): 19-28.

[Burzik, 2002] Burzik, A. 2002. Practising in Flow—The Secret of the Masters, Stringendo 24(2): 18-21.

[Hunt & Wanderley, 2002] Hunt, A. and Wanderley, M.M. 2002. Mapping performer parameters to synthesis engines. Organised Sound 7: 97-108.

[Hunt, Wanderley, & Paradis, 2003] Hunt, A. and Wanderley, M.M. and Paradis, M. 2003. The importance of parameter mapping in electronic instrument design, Journal of New Music Research 32(4): 429 - 440.

[Rovan et al., 1997] Rovan, J.B., Wanderley, M.M, Dubnov, S. and Depalle, P. 1997. Instrumental Gestural Mapping Strategies as Expressivity Determinants in Computer Music Performance. In: Kansei, The Technology of Emotion. Proceedings of the AIMI International Workshop, A. Camurri, (ed.), Genoa: Associazione di Informatica Musicale Italiana, October 3-4, pp. 68–73.

[Arfib et al., 2002] D. Arfib, J. M. Couturier, L. Kessous and V. Verfaille 2002. Strategies of mapping between gesture data and synthesis model parameters using perceptual spaces. Organised Sound 7: 127-144.

[Goudeseune, 2002] Goudeseune, C. 2002. Interpolated mappings for musical instruments. Organised Sound 7: 85-96.

[Wessel, 1979] Wessel, D. 1979. Timbre space as a musical control structure, Computer music journal 3(2): 45 – 52.

[Vertegaal & Eaglestone, 1996] R. Vertegaal and B. Eaglestone 1996. Comparison of input devices in an ISEE direct timbre manipulation task,
Interacting with Computers, 8(1): 13 – 30.

[Lyons et al., 2003 Lyons, M.J. and Haehnel, M. and Tetsutani, N. 2003. Designing, playing, and performing with a vision-based mouth interface, Proceedings of the 2003 conference on New interfaces for musical expression pp. 116—121.

[Steiner, 2006] H.-C. Steiner. Towards a catalog and software library of mapping methods. Proceedings of the 2006 conference on New interfaces for musical expression,
pp. 106–109, Paris, France, 2006. IRCAM Centre Pompidou.

[Cook, 2004] Cook, P. R. 2004. Remutualizing the musical instrument: Co-design of synthesis algorithms and controllers. Journal of New Music Research, 33(3):315-320.

[Bartneck & Lyons, 2007] HCI and the face: towards an art of the soluble. In J. Jacko (Ed.), *Human-Computer Interaction, Part 1, HCII2007, LNCS 4550* (pp. 20-29). Berlin: Springer.

Tools of NIME

[Fels et al. 2004] Sidney S. Fels and Linda Kaastra and Sachiyo Takahashi and Graeme McCaig. Evolving Tooka: from Experiment to Instrument. 4rd International Conference on New Interfaces for Musical Expression (NIME04). Pages 1-6. May. 2004.

[Wright and Freed, 1997] Wright, M. and A. Freed 1997. Open Sound Control: A New
Protocol for Communicating with Sound Synthesizers. Proceedings of the International Computer Music Conference, Thessaloniki, Hellas, pp. 101-104.

Sound Synthesis References:

General articles:
[Mathews & Pierce, 1989] Mathews, M. & Pierce, J. (1989). *Current Directions in Computer Music Research*. The MIT Press.

[Steiglitz, 1996] Steiglitz, K. 1996 Digital Signal Processing Primer,
New York, Addison Wesley.

[Roads, 1976] Roads, C. 1976, The Computer Music Tutorial, Cambridge, MIT Press

Additive synthesis:
[McAulay & Quatieri, 1986] McAulay, R. and T. Quatieri. 1986. "Speech Analysis/Synthesis Based on a Sinusoidal Representation." IEEE Trans. Acoust. Speech and Sig. Proc. ASSP-34(4): pp. 744-754.

[Smith and Serra, 1987] Smith, J. and Serra, X. 1987. "PARSHL: Analysis/Synthesis Program for Non-Harmonic Sounds Based on a Sinusoidal Representation." Proc. International Computer Music Conference, Urbana, pp. 290 – 297.

Subtractive Synthesis:
[Dudley, 1939] Dudley, H. 1939, "The Vocoder," Bell Laboratories Record, December.

[Moorer, 1978] Moorer, A. 1978. "The Use of the Phase Vocoder in Computer Music Applications." Journal of the Audio Engineering Society, 26 (1/2), pp. 42-45.

[Moorer, 1979] Moorer, A. 1979, “The Use of Linear Prediction of Speech in Computer Music Applications,” Journal of the Audio Engineering Society 27(3):134-140.

[Dolson, 1986] Dolson, M. 1986, "The Phase Vocoder: A Tutorial," Computer Music Journal, 10 (4), pp. 14 -27.

[Makhoul, 1975] Makhoul, J. 1975. "Linear Prediction: A Tutorial Review," Proc. of the IEEE, v 63., pp. 561-580.

FM synthesis:

[Chowning, 1973] Chowning, J. 1973, "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation," Journal of the Audio Engineering Society 21(7): pp. 526-534.

[LeBrun, 1979] LeBrun, M. 1979. "Digital Waveshaping Synthesis," Journal of the Audio Engineering Society, "27(4): 250-266.

Modal Synthesis:

[Adrien, 1988] Adrien, J. 1988. Etude de Structures Complexes Vibrantes, Application-la Synthèse par Modeles Physiques, Doctoral Dissertation. Paris: Université Paris VI.

Wawrzynek, J. 1989. "VLSI Models for Sound Synthesis," in Current Directions in Computer Music Research, M. Mathews and J. Pierce Eds., Cambridge, MIT Press.

[Larouche & Meillier 1994] Larouche, J. & J. Meillier 1994. "Multichannel Excitation/ Filter Modeling of Percussive Sounds with Application to the Piano," IEEE Trans. Speech and Audio, pp. 329-344.

Physical Modeling Approaches:

[Smith, 1987] Smith, J. 1987. Musical Applications of Digital Waveguides. Stanford University Center For Computer Research in Music and Acoustics. Report STAN-M-39.

[Karjalainen et al. 1991] Karjalainen, M. Laine, U., Laakso, T. and V. Välimäki, 1991. "Transmission Line Modeling and Real-Time Synthesis of String and Wind Instruments," Proc. International Computer Music Conference, Montreal, pp. 293-296

[Cook, 1991] Cook, P. 1991. "TBone: An Interactive Waveguide Brass Instrument Synthesis Workbench for the NeXT Machine," Proc. International Computer Music Conference, Montreal, pp. 297-299.

[Cook, 1991b] Cook, P. 1991b. "LECTOR: An Ecclesiastical Latin Control Language for the SPASM/singer Instrument," Proc. International Computer Music Conference, Montreal, pp. 319-321.

[Cook, 1992] Cook, P. 1992. "A Meta-Wind-Instrument Physical Model, and a Meta-Controller for Real-Time Performance Control," Proc. International Computer Music Conference, San Jose, pp. 273- 276.

[Cook, 1992b] Cook, P. 1992b. "SPASM: a Real-Time Vocal Tract Physical Model Editor/Controller and Singer: the Companion Software Synthesis System," Computer Music Journal, 17: 1, pp 30-44.

[McIntyre et al. 1983] McIntyre, M., Schumacher, R. and J. Woodhouse 1983, "On the Oscillations of Musical
Instruments," Journal of the Acoustical Society of America, 74(5), pp. 1325-1345.

Granular Synthesis:

[Roads, 1991] Roads, C. (1991). Asynchronous Granular Synthesis, In G. De Poli, A.

Piccialli, & C. Roads (Eds.), Representations of Musical Signals, pp. 143–185. Cambridge: MIT Press.

[Gabor, 1947] Gabor, D. (1947). Acoustical Quanta And The Theory Of Hearing. Nature,
159(4044), 591–594.

[Xenakis, 1971] Iannis Xenakis, Formalized Music: Thought and Mathematics in Composition. Bloomington and London: Indiana University Press, 1971.

[Truax, 1988] Truax, B. (1988) Real-time granular synthesis with a digital signal processor. Computer Music Journal, 12(2), 14-26.

Scanned Synthesis:
[Verplank, 2000] B. Verplank, M. Mathews, R. Shaw, "Scanned Synthesis", "Proceedings of the 2000 International Computer Music Conference", p: 368--371, Berlin, Zannos editor, ICMA, 2000.

Resources:
MIDI website: http://www.midi.org/
Sensors and A/D converters:
Infusion Systems: www.infusionsystems.com
Phidgets: www.phidgets.com
Arduino: http://www.arduino.cc/
National Instruments: http://www.ni.com/dataacquisition/
Digikey: http://www.digikey.com/
Jameco: www.jameco.com

Synthesizers:
STK from Perry Cook's page:
http://www.cs.princeton.edu/~prc/NewWork.html#STK
Perry R. Cook and Gary P. Scavone, The Synthesis ToolKit (STK), Proc of the ICMC, 1999.
G. Scavone and P. Cook, "RtMIDI, RtAudio, and a Synthesis (STK) Update," Proceedings of the International Computer Music Conference, Barcelona, September, 2005.

PureData: http://puredata.info/

JASS: http://www.cs.ubc.ca/~kvdoel/jass/jass.html
Kees van den Doel and Dinesh K. Pai, JASS: A Java Audio Synthesis System for Programmers, Proceedings of the International Conference on Auditory Display, pp. 150-154, 2001, Helsinki.

Max/MSP: http://www.cycling74.com/

Chuck: http://chuck.cs.princeton.edu/
[Wang & Cook, 2004] Wang, G. and Cook, P. R. 2004. On-the-fly programming: using code as an expressive musical instrument. In Proceedings of the 2004

Conference on New interfaces For Musical Expression (Hamamatsu, Shizuoka, Japan, June 03 - 05, 2004), 138-143.

Supercollider: http://supercollider.sourceforge.net// and http://www.audiosynth.com/

Aesthetics

[Kimura, 2004] Mari Kimura 2004, Performance at NIME-04, Hamamatsu, Japan.

[Wynnychuk, 2004] Jordan Wynnychuk 2004, Performance at NIME-04, Hamamatsu, Japan.

[D'Arcangelo, 2004] D'Arcangelo, G. 2004, Recycling music, answering back: toward an oral tradition of electronic music, Proceedings of the 2004 conference on New interfaces for musical expression, pp. 55-58.

[Okamoto, 2004] Hisashi Okamoto, 2004, Performance at NIME-04, Hamamatsu, Japan.

[Gadd & Fels, 2002] Gadd, A. and Fels, S. 2002. MetaMuse: metaphors for expressive instruments, Proceedings of the 2002 conference on New interfaces for musical expression, pp. 1-6.

[Fels et al., 2003] Fels, S. and Gadd, A. and Mulder, A. 2003. Mapping transparency through metaphor: towards more expressive musical instruments, Organised Sound 7(2): 109-126.

[Jorda, 2003] Jorda, S. 2003. Sonigraphical instruments: from FMOL to the reacTable, Proceedings of the 2003 conference on New interfaces for musical expression, pp. 70-76.

[Jorda et al. 2005] Jorda, S. and Kaltenbrunner, M. and Geiger, G. and Bencina, R. 2005.
The reactable*, Proceedings of the International Computer Music Conference (ICMC 2005) pp. 579 – 582.

[Mulder & Fels, 1998] Axel G.E. Mulder and S. Sidney Fels (1998). Sound Sculpting: Performing with Virtual Musical Instruments. Proceedings of the Fifth Brazilian Symposium on Computer Music (Belo Horizonte, Minas Gerais, Brazil, 3-5 August 1998, during the 18th Annual Congress of the Brazilian Computer Society, G. Ramalho (ed.)), pp. 151-164.

[Horio, 2004] Kanta Horio 2004. Performance at NIME-04, Hamamatsu, Japan.

[Fujii, 2004] Uriko Fujii 2004. Performance at NIME-04, Hamamatsu, Japan.

[Fels et al. 2002] Fels, Sidney, Gadd, Ashley, Mulder, Axel (2002). Mapping Transparency through Metaphor: Towards more expressive musical instruments, Organised Sound: Vol. 7, no. 2. Cambridge: Cambridge University Press: 109-126.

Case Studies

[Mathews & Schloss, 1989] Mathews, M.V. and A. Schloss The Radio Drum as a Synthesizer Controller, Proc. of the 1989 ICMC.

[Boei et al. 1989] Boie, R.A. et al. Gesture Sensing via Capacitive Moments. Work Project No. 311401-(2099,2399) AT&T Bell Laboratories, 1989.

[Young, 1991] Young, G. (1991), *The Sackbut Blues*: University of Toronto Press in Canada, and the University of Chicago Press in the USA. Issued also in French under the title: "Blues pour saqueboute: Hugh Le Caine, pionnier de la musique électronique." For further information phone +1/613 991-2983. The National Museum of Science and Technology houses an extensive collection of Le Caine's instruments.

[Buchla, 2005] Don Buchla. A History of Buchla's Musical Instruments., Proc. of NIME2005, Vancouver, BC, http://www.nime.org/2005/proc/nime2005_001.pdf

Paradiso, J., and Gershenfeld, N. Musical Applications of Electric Field Sensing. In Computer Music Journal 21(2) Summer, pp. 69-89. 1997.

[Palacio-Quintin, 2003] Palacio-Quintin, Cléo. The Hyper-Flute. In Proceedings of the New Interfaces for Musical Expression (NIME) Conference. Montreal, 2003.

[Young, 2001] Young, D., The hyperbowcontroller: Real-time Dynamics measurement of violin performance. In Proc. NIME, 2001.

[Marshall, 2009] Marshall, M., Physical Interface Design for DigitalMusical Instruments. Ph.D. thesis, McGill University, 2009.

[Fraser et al. 2008] Helene Fraser and Sidney Fels and Robert Pritchard. Walk the Walk, Talk the Talk. 12th IEEE 2008 International Symposium on Wearable Computing (ISWC2008). Pages 117--118. 2008.

[Pritchard & Fels, 2006] Pritchard, B. and Fels, S. 2006. GRASSP: gesturally-realized audio, speech and song performance. In Proceedings of the 2006 Conference on New interfaces For Musical Expression (Paris, France, June 04 - 08, 2006). New Interfaces For Musical Expression. IRCAM — Centre Pompidou, Paris, France, 272-276.

[Fels & Hinton, 2998] Sidney S. Fels and Geoffrey E. Hinton. Glove-TalkII: A neural network interface which maps gestures to parallel formant speech synthesizer controls. IEEE Transactions on Neural Networks. Volume 9. No. 1. Pages 205-212. 1998.

[Levin & Lieberman, 2005] Levin, G. and Lieberman, Z. "Sounds from Shapes: Audiovisual Performance with Hand Silhouette Contours in "The Manual Input Sessions". Proceedings of NIME '05, Vancouver, BC, Canada. May 26-28, 2005.

[Mulder & Fels, 1998] Axel G.E. Mulder and S. Sidney Fels (1998). Sound Sculpting: Performing with Virtual Musical Instruments. Proceedings of the Fifth Brazilian Symposium on Computer Music (Belo Horizonte, Minas Gerais, Brazil, 3-5 August 1998, during the 18th Annual Congres of the Brazilian Computer Society, G. Ramalho (ed.)), pp. 151-164.

[Huott, 2002] Huott, R. 2002. An interface for precise musical control. In Proceedings of the 2002 Conference on New interfaces For Musical Expression (Dublin, Ireland, May 24 - 26, 2002). E. Brazil, Ed., 1-5.
http://www.nime.org/2002/proceedings/paper/huott.pdf

[O'Modhrain & Essl, 2004] O'Modhrain, S. and Essl, G. 2004. PebbleBox and CrumbleBag: tactile interfaces for granular synthesis. In Proceedings of the 2004 Conference on New interfaces For Musical Expression (Hamamatsu, Shizuoka, Japan, June 03 - 05, 2004). M. J. Lyons, Ed., 74-79.

[Overholt, 2001] Overholt, D. 2001. The MATRIX: a novel controller for musical expression. In Proceedings of the 2001 Conference on New interfaces For Musical Expression (Seattle, Washington, April 01 - 02, 2001).

[Wang, 2009] Wang, G. 2009. Designing Smule's iPhone Ocarina, In Proceedings of the 2009 Conference on New interfaces For Musical Expression (Pittsburgh, PA, June 4-6, 2009).

[Merrill, 2003] Merrill, D. 2003. Head-tracking for gestural and continuous control of parameterized audio effects. In Proceedings of the 2003 Conference on New interfaces For Musical Expression (Montreal, Quebec, Canada, May 22 - 24, 2003). 218-219.
http://www.music.mcgill.ca/musictech/nime/onlineproceedings/Papers/NIME03_Merill.pdf

[Kapur et al. 2004] Kapur, A., Tzanetakis, G., & P.F. Driessen, "Audio-Based Gesture Extraction on the ESitar Controller," In Proceedings of the Conference on Digital Audio Effects, Naples, Italy, October 5-8, 2004.
http://soundlab.cs.princeton.edu/research/controllers/esitar/

[Vogt et al. 2002] Vogt, F., McCaig, G., Ali, M. A., and Fels, S. 2002. Tongue 'n' Groove: an ultrasound based music controller. In Proceedings of the 2002 Conference on New interfaces For Musical Expression (Dublin, Ireland, May 24 - 26, 2002).
http://www.nime.org/2002/proceedings/paper/vogt.pdf

[Takaka & Knapp, 2002] Tanaka, A. and Knapp, R. B. 2002. Multimodal interaction in music using the Electromyogram and relative position sensing. In Proceedings of the 2002 Conference on New interfaces For Musical Expression (Dublin, Ireland, May 24 - 26, 2002.
http://www.nime.org/2002/proceedings/paper/tenaka.pdf

[Knapp & Lusted, 1990] R. Benjamin Knapp and Hugh Lusted - A Bioelectric Controller for Computer Music Applications, Computer Music Journal, Volume 14 No. 1, New Performance Interfaces 1 - Spring 1990; pg 42-47.

[Nagashima, 2003] Nagashima, Y. 2003. Bio-sensing systems and bio-feedback systems for interactive media arts. In Proceedings of the 2003 Conference on New interfaces For Musical Expression (Montreal, Quebec, Canada, May 22 - 24, 2003), 48-53.
http://www.nime.org/2003/onlineproceedings/Papers/NIME03_Nagashima.pdf

[Fels et al. 2004] Sidney S. Fels and Linda Kaastra and Sachiyo Takahashi and Graeme McCaig. Evolving Tooka: from Experiment to Instrument. 4rd International Conference on New Interfaces for Musical Expression (NIME04). Pages 1-6. May. 2004.

[Fels & Vogt, 2002] Sidney S. Fels and Florian Vogt. Tooka: Explorations of Two Person Instruments. 2nd International Conference on New Interfaces for Musical Expression (NIME02). Pages 116-121. May. 2002.

[Carlile & Hartmann, 2004] Carlile, J. and Hartmann, B. 2004. OROBORO: a collaborative controller with interpersonal haptic feedback. In Proceedings of the 2005 Conference on New interfaces For Musical Expression (Vancouver, Canada, May 26 - 28, 2005), 250-251.

[Chadabe, 2002] Chadabe, J. 2002. The limitations of mapping as a structural descriptive in electronic instruments. In Proceedings of the 2002 Conference on New interfaces For Musical Expression (Dublin, Ireland, May 24 - 26, 2002).

[Blaine & Fels, 2003] Tina Blaine and Sidney S. Fels. Collaborative Musical Experiences for Novices. Journal of New Music Research. Volume 32. No. 4. Pages 411-428. Dec. 2003.

[Blaine & Perkis, 2000] Tina Blaine and Tim Perkis: The Jam-O-Drum Interactive Music System: A Study in Interaction Design. Symposium on Designing Interactive Systems 2000: 165-173

[Paradiso, 1999] Paradiso, J., The Brain Opera Technology: New Instruments and Gestural Sensors for Musical Interaction and Performance. Journal of New Music Research, 1999. 28(2): p. 130--149.

Resources:

Theremin:
wikipage: http://en.wikipedia.org/wiki/Theremin
Oddmusic page: http://www.oddmusic.com/theremin/
Theremin enthusiast page: http://theremin.ca/
Where to buy: Moog Music - http://www.moogmusic.com/
Clara Rockmore video: http://www.youtube.com/watch?v=pSzTPGlNa5U
More video of people playing Theremin: http://www.youtube.com/watch?v=h-3lU3bgOgE

Hugh Le Caine: Electronic Sackbut:
http://www.sciencetech.technomuses.ca/english/collection/music7.cfm

Hugh Le Caine info site: http://www.hughlecaine.com

Bucla's instruments: http://www.buchla.com/
Wikipage: http://en.wikipedia.org/wiki/Buchla

Michel Waisvisz
wikipage: http://en.wikipedia.org/wiki/Michel_Waisvisz
2005 talk at CHI2005: http://www.chi2005.org/program/prog_closing.html

Lady's Glove, Laetitia Sonami
http://www.sonami.net/lady_glove2.htm
Video: http://www.sonami.net/Clips/VideoPerf_clips/China-Loose.mov

Pebblebox video:
http://www.youtube.com/watch?v=GEJCmrhrBjc
http://www.sarc.qub.ac.uk/~somodhrain/palpable/projects.html#enactivemi

Info on circuit bending:
http://en.wikipedia.org/wiki/Circuit_bending

Info on Cracklebox:
http://www.crackle.org/

iPhone musical applications:
Smule: http://ocarina.smule.com/

Tooka publications:
NIME02: http://www.nime.org/2002/proceedings/paper/fels.pdf
NIME04: http://www.nime.org/2004/NIME04/paper/NIME04_1A01.pdf

OROBORO site: http://regexp.bjoern.org/archives/000159.html

Jamodrum site: http://www.jamodrum.net/

Brain Opera information: http://park.org/Events/BrainOpera/

Penn playing with Brain Opera sensor chair video:
http://www.media.mit.edu/~joep/MPEGs/penn.mpg

Monome Open Hardware Interface
http://monome.org

Visual Interfaces

[Tarabella, 2004] Leonello Tarabella, 2004. Performance at NIME-04, Hamamatsu, Japan.

[Fels & Mase, 1999] Sidney S. Fels and Kenji Mase. Iamascope: A Graphical Musical Instrument. Computers and Graphics. Volume 2. No. 23. Pages 277-286. 1999.

[Lyons et al., 2001] Lyons, M.J., Haehnel, M., and Tetsutani, N. 2001. The mouthesizer: A facial gesture musical interface. Conference Abstracts, ACM SIGGRAPH 2001.

[Lyons, 2004] Lyons, M.J., Facial gesture interfaces for expression and communication. 2004 IEEE Conference on Systems, Man, and Cybernetics, 2004.

[Lyons & Tetsutani, 2001] Lyons, M.J. and Tetsutani, N. 2001, Facing the music: a facial action controlled musical interface, Conference on Human Factors in Computing Systems, (CHI'2001), Extended Abstracts, pp. 309—310.

[Funk et al. 2005] Funk, M. and Kuwabara, K. and Lyons, M.J. 2005. Sonification of facial actions for musical expression, Proceedings of the 2005 conference on New interfaces for musical expression, pp. 127—131.

[De Silva et al. 2004] A novel face-tracking mouth controller and its application to interacting with bioacoustic models. Proceedings of the 2004 conference on New interfaces for musical expression, pp. 169- 172.

[Nishibori & Iwai, 2006] Nishibori, Y. and Iwai, T., 2006. Tenori-On, Proceedings of the 2006 conference on New interfaces for musical expression, pp. 172 – 175

Education

[Cook, 2001] Cook, P. 2001. Principles for designing computer music controllers, Proceedings of the 2001 conference on New interfaces for musical expression, Seattle WA.

[Cook, 2007] Cook, P. 2007, Keynote Talk at the 2007 Conference on New Interfaces for Musical Expression, New York, NY.

[Jorda, 2004] Jorda, S. 2004. Digital instruments and players: part I---efficiency and apprenticeship, Proceedings of the 2004 conference on New interfaces for musical expression pp. 59 – 63.

[Singer, 2003] Singer, E. 2003. Sonic Banana: A novel bend-sensor-based midi controller, Proceedings of the 2003 conference on New interfaces for musical expression, pp. 220 – 221.

Vienna Vegetable Orchestra
http://www.gemueseorchester.org

[Igoe, 2007] Igoe, T. 2007. Making Things Talk, O'Reilly.

[Verplank, Sapp, & Mathews, 2001] Verplank, B. and Sapp, C. and Mathews, M., A Course on Controllers, Proceedings of the 2001 conference on New interfaces for musical expression, Seattle, WA.

[Lippit, 2004] Lippit, T.M. 2004. Realtime sampling system for the turntablist version 2: 16padjoystickcontroller, Proceedings of the 2004 conference on New interfaces for musical expression, pp. 211—212.