Gestural control of audio systems and digital musical instruments

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Interactive audio systems and HCI

- highly specialized branch of HCI
- Some characteristics (Hunt & Kirk):
  - no fixed ordering to the human-computer dialogue
  - no single permitted set of options but rather a series of continuous controls
  - instant response to user’s movements
  - Further practice develops increased control intimacy and thus competence of operation
Interactive audio systems and Digital Musical Instruments

• Different types of interactive audio systems
  – Interactive sound installations
  – Musical instruments
  – Dance/music interfaces
  – (Computer games)

• Digital musical instruments

  Same functions as acoustical instruments:
  • Real time control of sound
  • Dedicated to play music: importance of aesthetics
Problem in digital instrument design

• Acoustic instruments:
  Causal link between the gestures and the resulted sound

• Digital instruments:
  The natural gesture-sound link disappears
Outline

1. Historical overview
2. Digital musical instruments
3. Examples from CNRS/LMA
From sound synthesis beginnings to nowadays: some examples
The Theremin (1920)
Computer synthesis

- Max Mathews 1957
Music V : modularity

```
COM--------------------------;
INS 0 1;
P9_HZ(W9) P6_HZ(W6) P7_HZ(W7) P8_HZ(W8)
P5_W5/4;
IOS P5 P8 B3 F1 P30;
IOS P7 P8 B4 F1 P29;
AD2 B4 P6 B4;
IOS B3 B4 B3 F1 P28;
IOS B3 P8 B4 F4 P26;COM DTE GCHE;
SB2 B3 B4 B3;
STR B3 B4 B1;END;
COM--------------------------;
```
Analog Synths : Moog (1964)

- Theme from A Clockwork Orange (Beethoviana), Wendy Carlos 1972
Digital Synthesis, FM
(John Chowning 1967, DX7 1983)
The MIDI protocol (1983)

- Standard to exchange data between machines
- Digital data
- Adapted to Keyboards-like interface
- Still used today, despite of its inconveniences
Don Buchla - MIDI controllers

- Thunder (1990)
- Lightning (1991)
« The hands » , Michel Waiswisz
Mouthesizer, M. Lyons
bioelectric sensors
Atau Tanaka
Tangible interfaces

Audio Pad
Digital musical instruments
musician - instrument relationships

action - perception loop
Digital musical instruments

- Sound processes
- Mapping: link between gesture and sound

Visual feedback
Hardware / Software

• Controllers: hardware (sensors)

• Data management / Sound production:
  – Programmers:
    Max/MSP, Pure Data
  – Low end users:
    standalone, plug-ins, virtual instruments
Sound processes

• **Synthesis methods**
  – Wave table synthesis
  – Additive synthesis
  – Subtractive synthesis
  – FM and non-linear distortion
  – Granular synthesis
  – Physical models

• **Digital audio effects**
  Act on: dynamic, time, pitch, space, timbre (envelope, phase, spectrum)
Gesture in digital musical instruments
Instrumental gesture

- Gesture is « all corporal behaviours associated to our muscular activity » [Cadoz, 1999].

- *Instrumental gestures*: gestures that are involved into creation or modulation of the produced sound
Gestures of musicians

- action - perception loop:
  Learning and perfection
- Current tools: action -> result
- Instrument: action <=> result
  - strong synchronicity of gestures
  - Learning time
Gesture typology

- Excitation gestures: give the energy that is need to produce sound
- Modification gestures: modify a sound during its lifetime
- Selection gestures

Others: preparatory gestures
Controllers’ typology

- Direct acquisition
  - Haptic
    - Invasive
    - non invasive
  - non haptic

- Indirect acquisition

- Hybrid systems
Type of gestural controllers

- Imitation of acoustical instruments
- Alternative controllers
## Compare controllers

### taxonomy

- **s**: USB mouse
- **c**: QWERTY kbd
- **j**: joystick (Saitek Cyborg 3D Gold)
- **g**: graphical tablet (Wacom Intuos 2)
- **p**: Pointing Fingers (1 finger)

### Table

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## Diagram

The diagram visualizes the comparison of different controllers based on their movement capabilities in both translation and rotation axes. Each controller is represented by a node, and the connections indicate how they map to the axes:

- **P**: Pointing Fingers
- **F**: Graphical tablet (Wacom Intuos 2)
- **A**: Joystick (Saitek Cyborg 3D Gold)
- **dP**, **dF**, **dT**: Derivatives or specific configurations of each controller.
Feedbacks
Feedbacks

- Musician
- Instrument
- Gesture
- Feedback
  - Auditory
  - Visual
  - Haptic
Feedbacks

- **Primary feedback**
  - Auditory
  - Visual
  - Haptic

- **Secondary feedback**
  - Auditory
  - Visual
  - Haptic

- **Gesture**
  - **Musician**
  - **Instrument**
    - **Control interface**
Auditory feedback
Visual feedback

Beginner: look at his gestures

Other musicians

Scores

Audience

Secondary feedback:
  Video
  Graphical interfaces
Haptic feedback

« A gesture is characterized by the indissociable interweaving of its motor function and its perceptive function » [Gibet 1988]

- Tactile
- Kinaesthetic
- Proprioceptive
Mapping: link between gesture and sound
Mapping

Gesture sensor → Gesture data → Mapping → Synthesis parameters → Synthesis model → Sound
Modularity in the Mapping

3-layer model

Gesture transducer → Gesture Mapping → Mapping between relevant parameters → Sound Mapping → Synthesis parameters → Synthesis model → Sound

Gesture data → Gesture Mapping → Mapping between relevant parameters → Sound Mapping → Synthesis parameters

Relevant parameters
Mapping Attributes (1/3)

- Explicit
  - Mathematical functions
- Implicit (black box)
  - Statistical tests
  - Neural networks
  - Maximum estimation in a data basis
Mapping Attributes (2/3)

- **Simple**
  - “One to one”

- **Complex**
  - “Many to many”
  - output = combination between several inputs
Mapping Attributes (3/3)

- **Static**
  - \( s(t) = F(e(t)) \)
- **Dynamic**
  - \( s(t) = F(e(t), e(t-1), \ldots) \)
  - Mechanical systems
  - Genetic algorithms
Managing data
About control data

• Temporal data: $x(t)$
• Sampling rate
  – Audio: 44100 Hz (CD standard)
  – Control: between 50 and 1000 Hz, best: > 100 Hz (10 ms)
• Latency time
  – Interval between an action and the response of the system to this action
  – Best: > 10 ms for musical control
Data types

- Discontinuous
  - Trigger
  - $x = 0$ or $1$
  - Example: triggering of temporal envelopes
    ADSR (Attack, Decay, Sustain, Release)
Data types

• Discontinuous
  – Trigger
  – $x = 0$ or $1$
  – Example: triggering of temporal envelopes

• Continuous
  – Limits: variation scales
  – Resolution (example: MIDI data $\rightarrow$ 7 bits $= 128$ values)
  – Lists and matrixes

$x_{\text{min}} \quad x_{\text{max}}$
Simple data transformations

- Changing scales
- Use tables
- Division into several areas
- Time transformations:
  - Delays
  - Smoothing
Presets

• Storing parameters values
  – All parameters cannot be controlled simultaneously
  – Fix some parameters to constant values

• Choice of presets:
  – Selection gesture
  – Modulation gesture: interpolation
Interpolation between parameters

Continuous transition between presets

• 1D interpolation
  – Go to one preset to another using a continuous parameter
  – \( S(x) = A \cdot x + B \cdot (1-x) \)  with  \( x \in [0 ; 1] \)

• 2D interpolation
Principle of 2D interpolation

Initial vectors

Resulting Vector

\[ C_i \]

\[ r_i \]

\[ d_i \]

X

Y
Digital musical instruments: some examples developed at CNRS/LMA
The Voicer

Interpolation between vowels

Circular control of pitch
The Voicer
Scanned synthesis

Control parameters:

String parameters

String shape: wavetable

Scanning frequency

scanning

Sound

Slow movements

\( M_{i-1} \quad M_i \quad M_{i+1} \)
Scanned synthesis

Curves manipulated by metaparameters

Control parameters:

String parameters

String shape: wavetable

Scanning frequency

scanning

Sound
Scanned Synthesis: graphical interface
Scan gloves

- Scanned Synthesis controlled with gloves
Filtering String

Sound input: noise, samples, ...

Forces on the string

Physical parameters of the string
Photosonic Emulator

Emulator created by Daniel Arfib from the Photosonic Synthesiser of Jacques Dudon
Photosonic Emulator
Graphical interfaces in the control of sound processes
Graphical interfaces

- Implemented in most computers
- Current interfaces: not suitable for sound process control
  - Only one hand involved
  - Actions performed one after the other
- Post-WIMP interaction
Graphical interfaces: examples

- Graphical objects
- Dynamic virtual objects
- Mixed reality
- 3D interfaces
Design graphical interfaces: different strategies

1. Generic interaction techniques: independent from sound processes
2. Start from specificities of the sound process to design the graphical interface
Etheraction
Wave terrain synthesis

A trajectory runs on a 3D terrain

different types of trajectories

Graphical interface
Conclusion

• Digital musical instrument
  – Specific interactive system
  – Recreate the link between gesture and sound
  – Importance of the mapping

• Tomorrow instruments?
  – Use of visual and haptic feedbacks
  – Up to you to create them …
Thanks for your attention

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