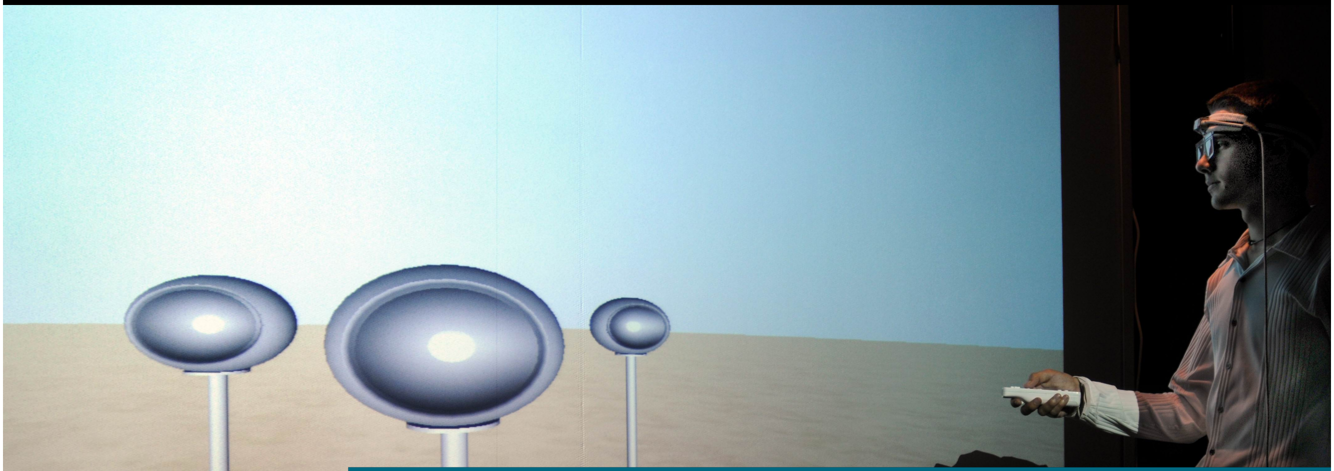


Advanced Auditory Displays

Fundamentals of Virtual and Augmented Reality (TC2)
M2: Research Speciality in Human-Computer Interaction
The University of Paris-Sud

Authors: Marc Evrard, Tifanie Bouchara & Brian Katz: LIMSI-CNRS
marc.evrard@limsi.fr, tifanie.bouchara@limsi.fr, brian.katz@limsi.fr

Outline of lecture #2

1) Introduction: sound walking, auditory displays

2) Sonification: science, sport, virtual reality (VR)…

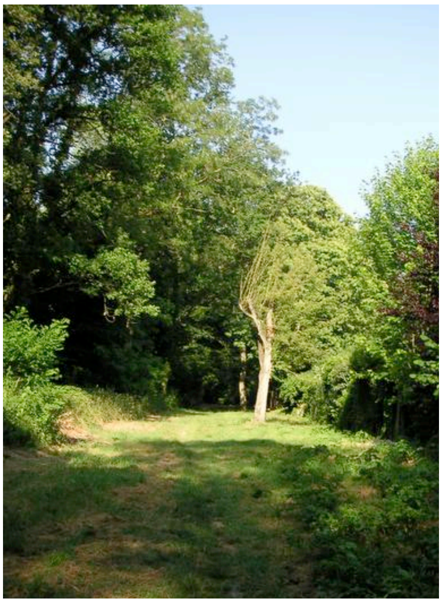
3) Audio and augmented reality (AR):
interfaces for visually impaired individual,
or other audio AR concepts

4) Design and conception process:
audio sketching, sound synthesis, sound software

5) Multimodal perception:
A/V illusions, A/V facilitations

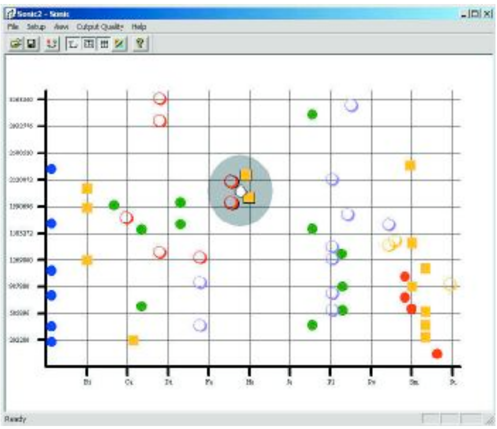
Sound walking

Becoming conscious of the different sounds in our environment



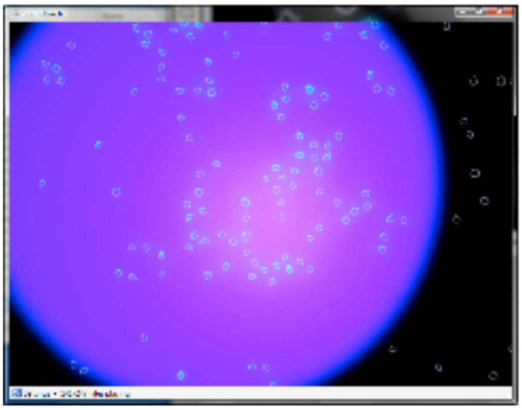
Auditory interfaces with spatialization

Browse large collection of sounds



The Sonic Browser
[Fernström&Brazil, 2001]

VIDEO



SoundTorch
[Heise et al., 2008]

VR and audio: applications

Transmodality

Using sound to illustrate data from another modality

- sound can indicate impact (haptic substitution)
- change in frequency may indicate a change in temperature (thermic substitution): everyday example = sound of a kettle

Sonification

Presentation of complex data through sound

- E.g. "listen to a graph" (mathematics)

Auditory display requirements

- **Rapid detection**: shorter response time than with visual stimuli
- **Alerting**: good for alarms since sound gives short response time and good direction cue, whatever the user initial orientation
- **Noise attenuation**: possibility to ignore sounds that don't need attention
- **Parallel listening**: able to listen to multiple sources at a time
- **Accurate temporal resolution**
- **Affective response**: subtle qualitative information may be conveyed

Usual defects of auditory displays

Annoying

If sounds not well chosen => distracting and irritating
=> The user will disable the audio portion of the interface!

Interferes with speech

Problematic in work environment, or even at home

Not bounded by Line-of-Sight

Intimacy problems: audio can be heard throughout the environment
Especially in open settings like cubicles in offices

Unusual

User needs to learn and get used to the sound interfaces

Sonification outline

1) Audification

2) Sonification for sciences

3) Sonification for sport

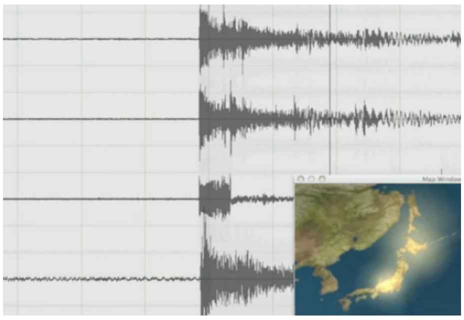
4) Other interface concepts

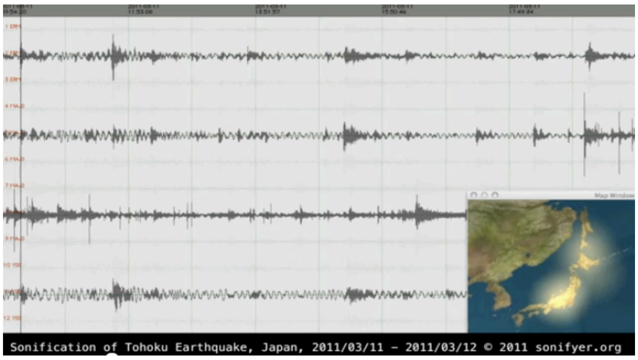
Basic sonification: audification

Straight signal-to-sound conversion

Changing the time/frequency scale of available data to make them audible

Applicable to time series



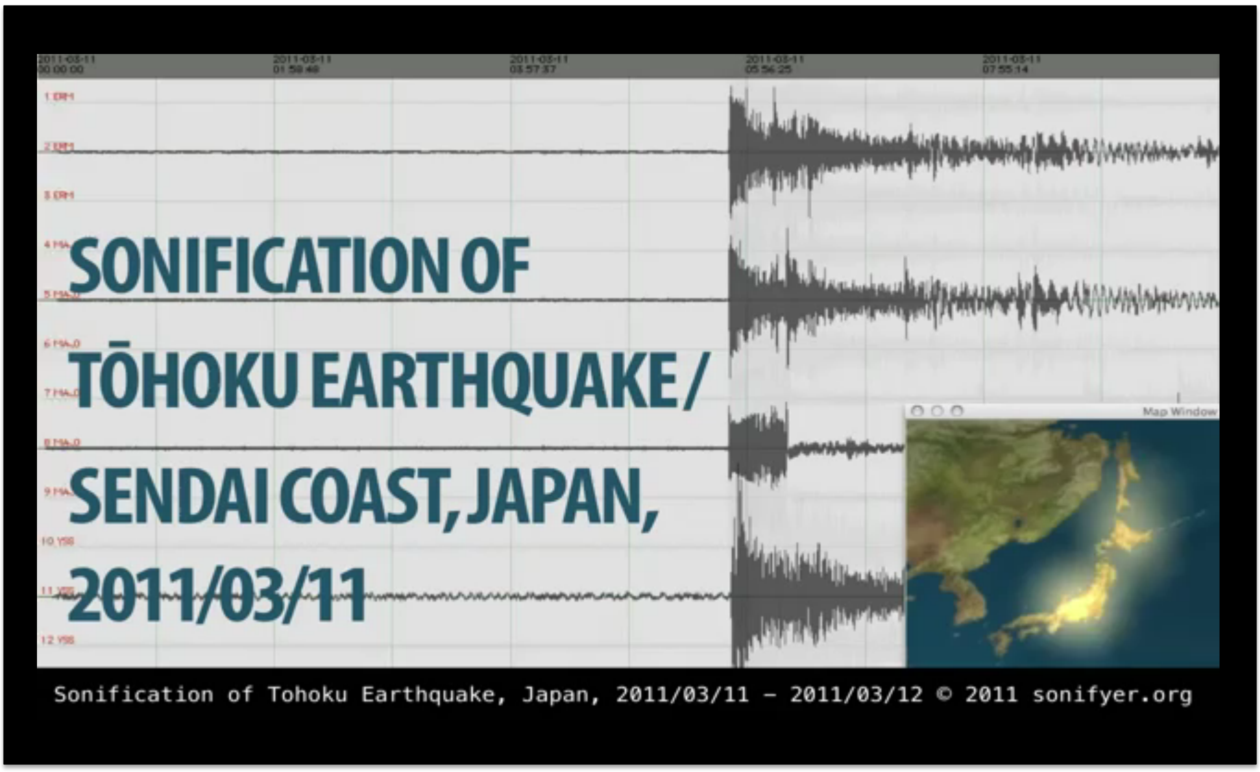


E.g. **Earthquake sonification**

The seismic signal, made audible by an acceleration factor of 1440

The ground motion of two days is converted in an audio track of 120 seconds

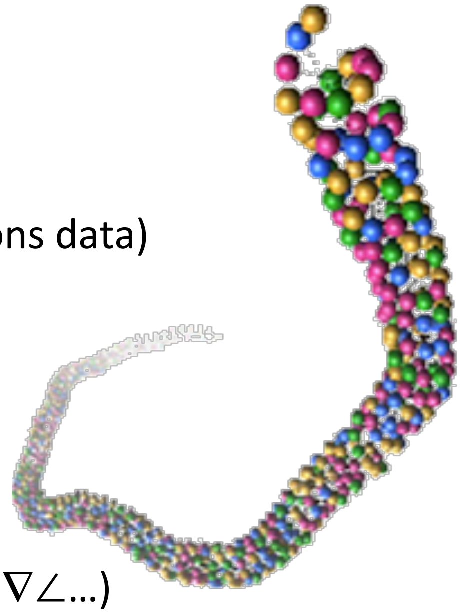
Basic sonification: audification



Sonification: data to sound

Mapping data to sound

- To better understand scientific data
- Enhance graphical representations
- Keep coherence (time data / vibrations data)
- When there's no space relationships



Applications to data exploration

Complex geometry system

Multi-dimensional data spaces (p, $\nabla\angle$…)

Dynamic simulation

Mapping data to sound

Representation of complex information using sound

– Match element properties with sound properties

– Complex relationship between nearby elements

– Exploits natural sound perception to detect:
pattern, change in pattern, harmony, etc.

Mapping is not obvious [Walker and Kramer 2005]:

Semantic, metaphoric or intuitive mapping?

Direct or indirect mapping?

Examples

Bend ➢ Frequency
Differentiate ➢ Amplitude
Composition ➢ Modulation

Well known example: Geiger counter

Particle detector that measures ionizing radiation

Each detected particle produces a pulse of current:

More particles => more pulses

Pulse rate = number of particules

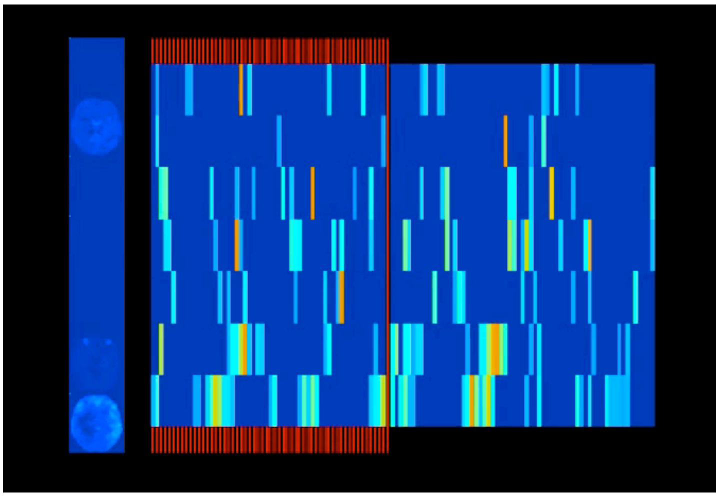
Brain activities

EEG (ElectroEncephaloGraphy) data
or fMRI (Functional Magnetic Resonance Imaging) data

With 3D audio:
study source location type
timing for neural events

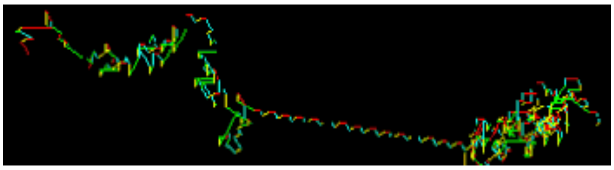
VIDEO

The dynamic brain [Lloyd 2009]



DNA sonification

Molecules sonification: e.g. DNA
Audio display of hierarchical biological information



DNA1: Design Rhythmic Sonification Research Lab
http://www.quinnarts.com/srl/index.html

nucleic acid elements
=> various parts of a drumset:

A for snAre C for Cymbals
T for Toms G for hiGh hat

3 amino acid interpretations
=> 3 instruments

Relationships between each of 12 pairs of nucleic acids (ag, ga, cg, ct , tc, gc, …)
=> Marimba

DNA 2:

amino acids => violins
hydrophobic amino acids => higher pitched violin sounds

Protein sonification

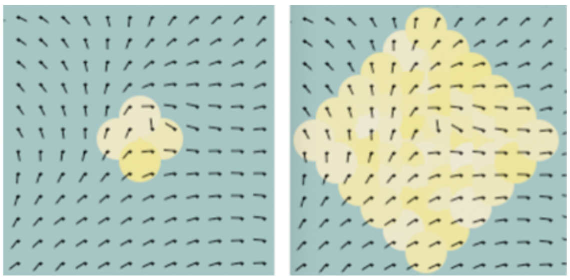
VIDEO

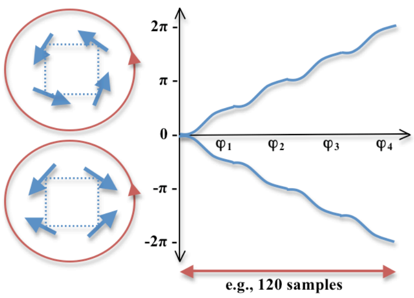
Flow sonification

VIDEO

Spin vortices sonification

Orientation of spin quartets





http://www.qcd-audio.at/results/xy

Vogt *et al. (IEM/CERN)*

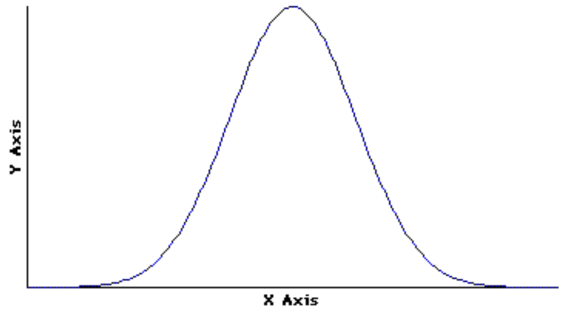
VIDEO

Other examples of scientific sonification

IEM: http://www.qcd-audio.at/results

Auditory graphs

Help visually impaired people to learn mathematics

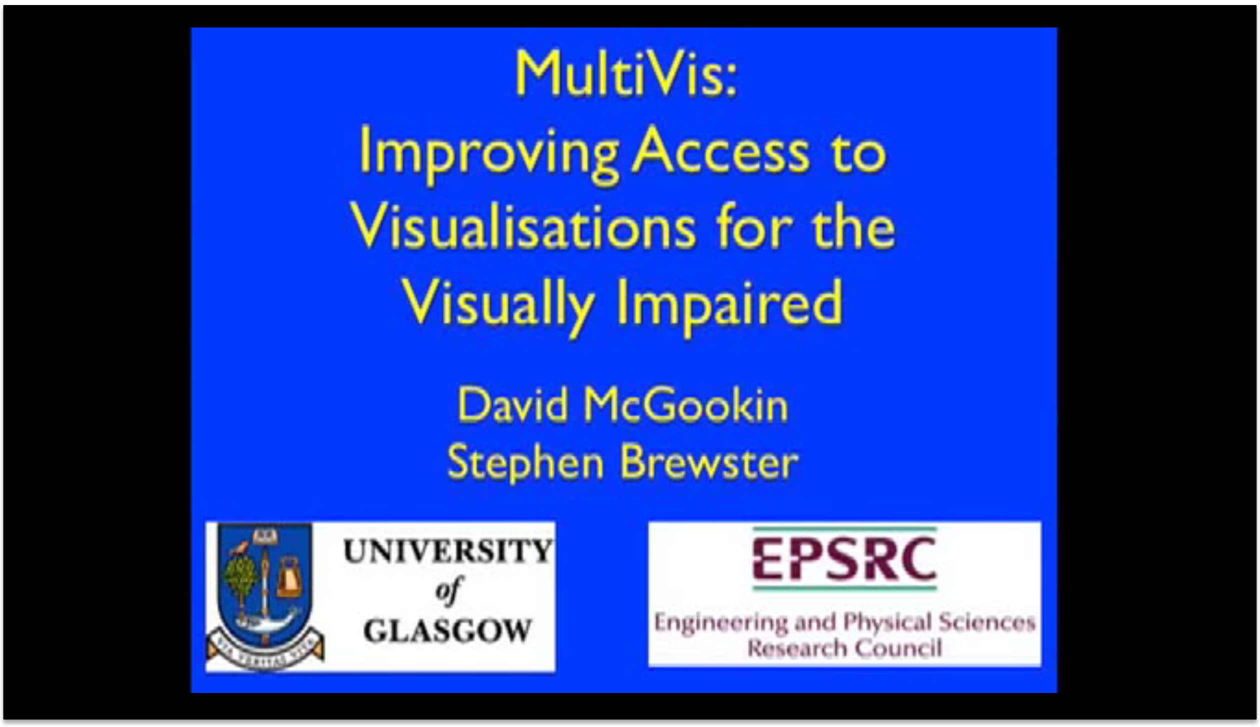


http://sonify.psych.gatech.edu/research/auditorygraphs/auditory_graphs_explained.html

What do you hear?

Auditory graphs: audio + haptic

VIDEO

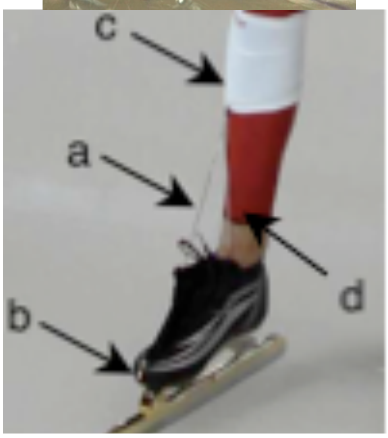


Geo-exploration for vision impaired

VIDEO

Sport: aiding movements

To synchronize several sportsmen [Dubus2010]

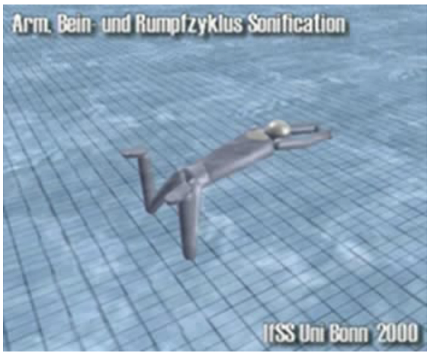


To correct gestures [Godbout2011]

Medical applications
Gain of performances

Sport: aiding movements

Off-time sonification: to control
to decompose the different motions



Auditory icons

Auditory icons

Natural sounds

Earcons

Abstract, electronic sounds

Open   Close   Edit

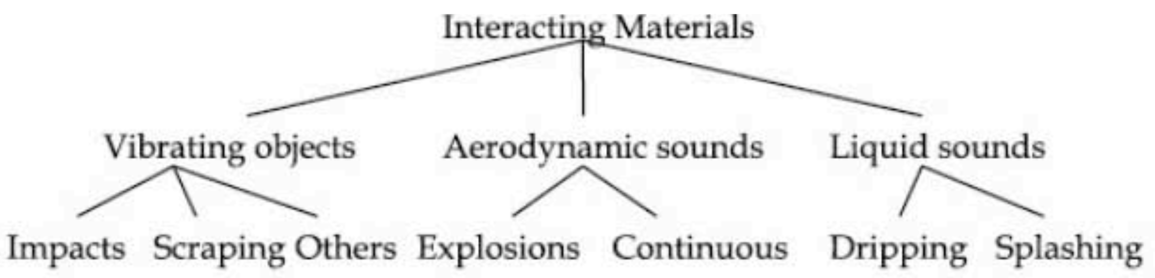
mapping event to sounds

Spearcons

Brief non-speech sound
Created by speeding the short utterance to the TTS (text-to-speech)

ParkingMeter   Elevator

Auditory icons: taxonomy



Taxonomy of everyday sounds [Gaver 1993]

Earcons

Non-verbal audio messages
that are used in the computer/user interface
to provide information to the user
about some computer object, operation or interaction.
[Blattner]

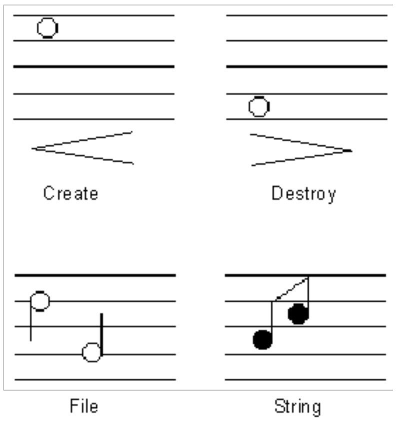
- Synthetized sound
- Non-intuitive link => must be learned

Built from motif
A **motif** = short, rhythmic sequence of pitches
that can be combined in different ways

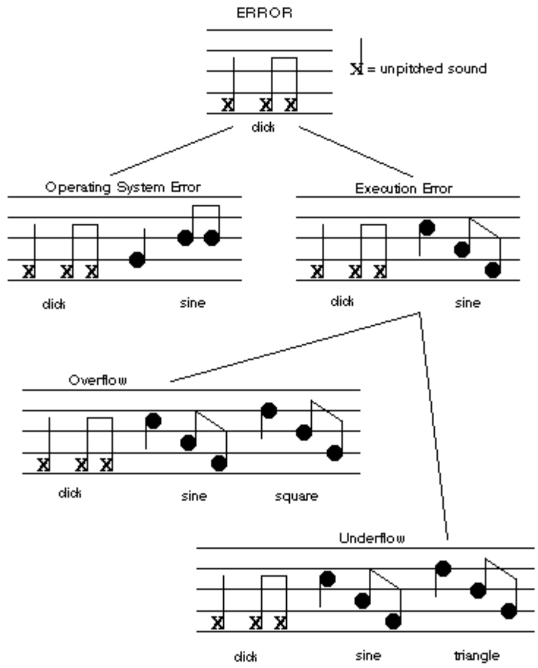
- Rhythm
- Pitch
- Timbre
- Register
- Dynamics

Earcons

Compound earcons



Hierarchical earcons



http://www.dcs.gla.ac.uk/~stephen/generalearcons/generalearcons2.shtml

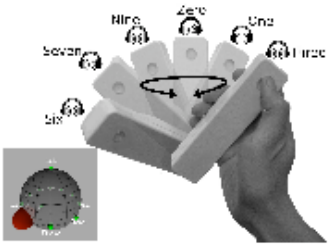
Auditory menu and earcon examples

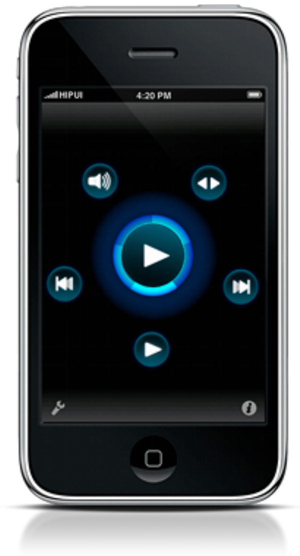
Hierarchical earcons => auditory menus

http://www.dcs.gla.ac.uk/~stephen/earconexperiment1/earcon_expts_1.shtml

Auditory menus

Eyes-free method of navigation
through a menu structure





Basic auditory menus =
text-to-speech (TTS) synthesis

Advanced auditory menus =
spearcons
spindexes (brief speech sounds that are used to speed up navigation)
auditory scrollbars

Virtual reality: steps

Virtual reality problems: immersion when walking?
=> small walking surfaces
interactive sounds for steps
+ soundscape design for environment

Virtual reality: steps

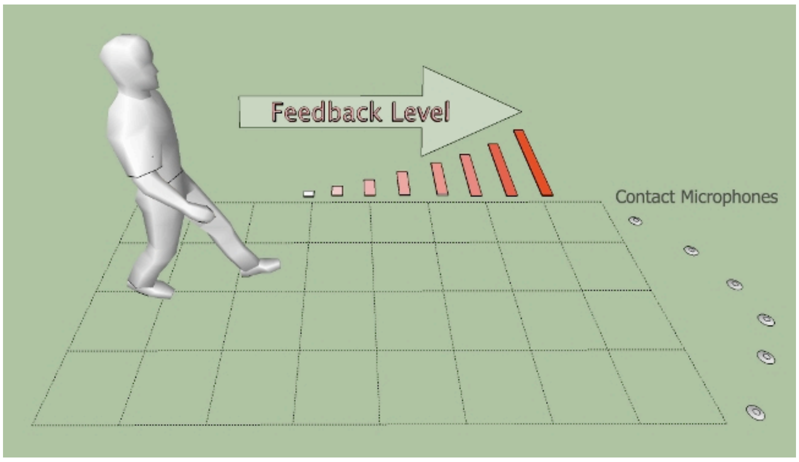
VIDEO

Virtual reality: steps

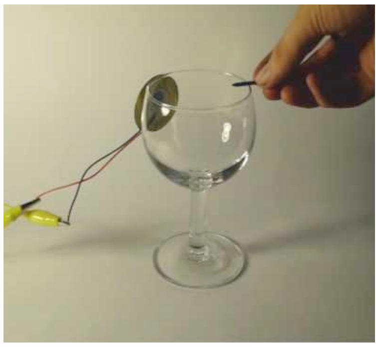
Audio Haptic Footwear

Simulate a Natural Interactive Walking (NIW) on different surfaces

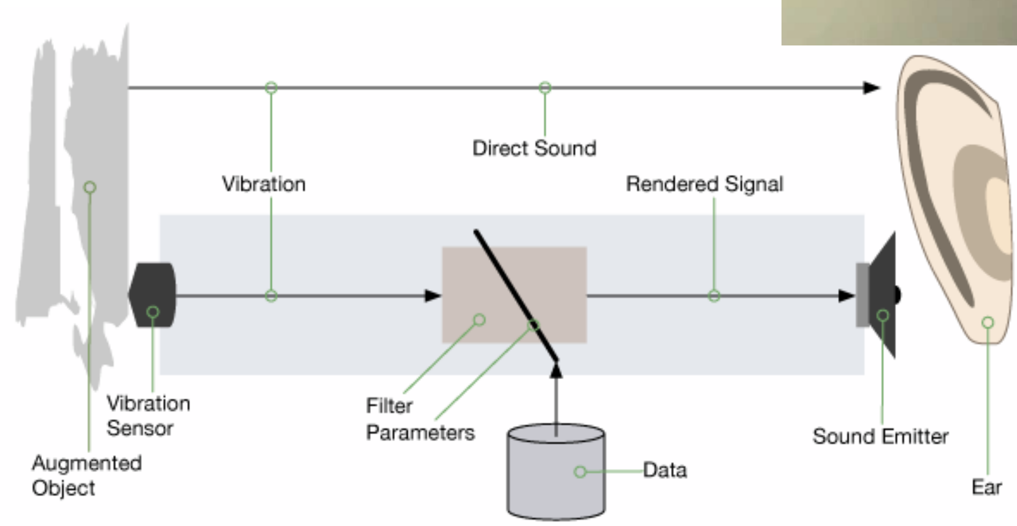
Vibrotactile shoes + sound renderings



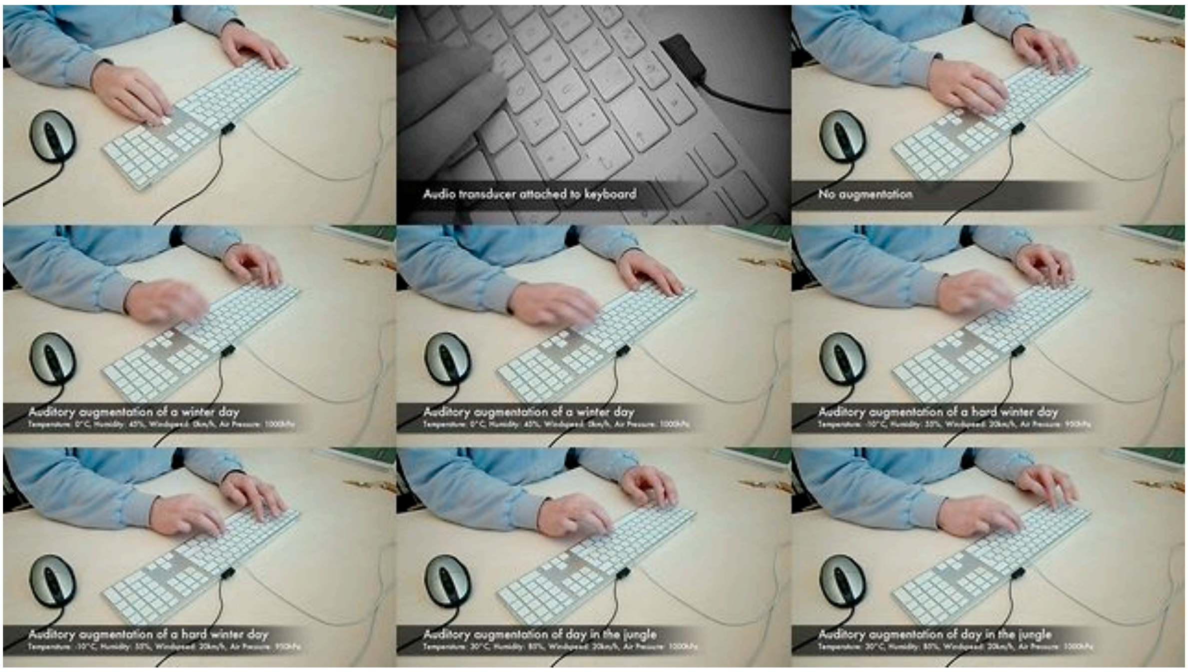
Auditory augmentation



Altering sounds of our everyday lives to provide information about our environment



Auditory augmentation



http://tangibleauditoryinterfaces.de/index.php/tai-applications/auditory-augmentation/

Sensory substitution

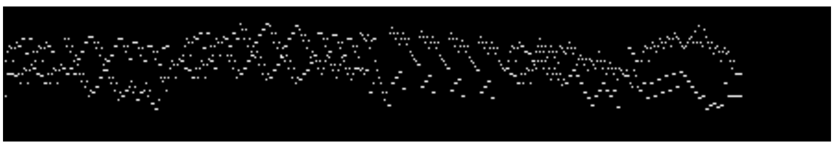
Make the **information accessible for everyone all the time**
- For visually impaired people
- In case of visual overload or when vision is unavailable

Navigational systems

Replace visual data with audio

The vOICe
http://www.seeingwithsound.com/javoice.htm

Example: Suite de Bach avec The vOICe



Wayfinding systems

Replace vision with audio

Examples: navigation system NAVIG
http://navig.irit.fr/

Near-field

Object recognition
+ metaphoric representation of objects

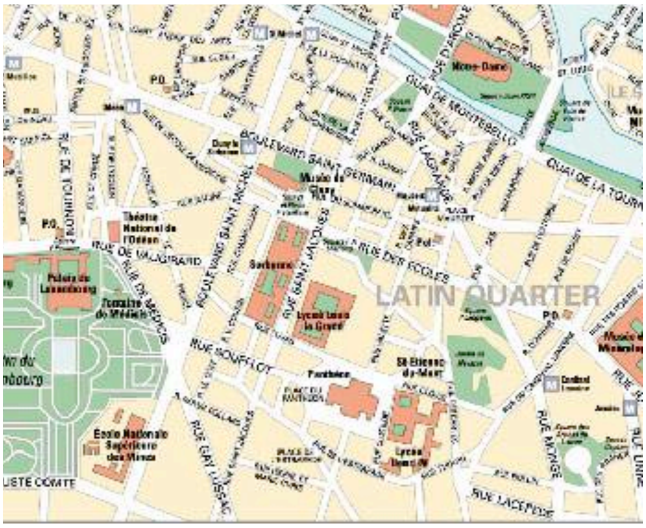
Geolocalization

GPS information
are rendered through sounds

Wayfinding sounds in NAVIG

	Itinary points	Alert	Point of Interest	Preferred point	Reference point
Reference tone					
Theme 1					
Theme 2					
Theme 3					

Audio city maps



Audio city maps

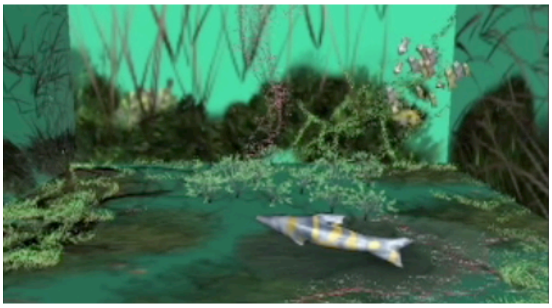
Augmented aquaria

Dynamic exhibits accessible for everyone (visually impaired people too!)

Real-time interpretations of the exhibits:

Tracking of the visitor
+ Narrations (speech comments)
+ Adaptive sonification (music production)

How?



http://sonify.psych.gatech.edu/research/aquarium/index.html

Augmented aquaria

Audio sketching

Trying before implementing

(before setting a **Wizard of Oz experiment)**

1) Vocal sketching
2) Electronic prototyping
3) Final implementation

What to model?

Body generated sounds
Material collisions & sliding surfaces
Simultaneous sounds
Sounds from nature
Narration & Storytelling

Audio sketching

Exercise 1: robot emotion

Why?

To understand that sound transfers emotions and meaning

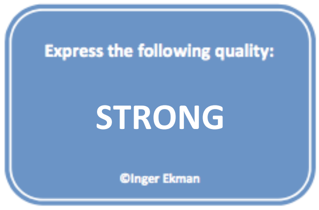
Rules:

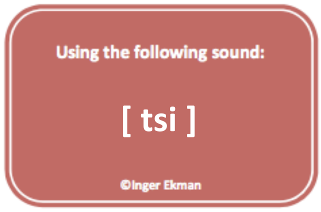
Goal: score the most points

1 point = 1 card correctly guessed

1) Pick a blue card with a word
2) Pick a red card with an onomatopoeia
3) Try to make others guess the blue word
   by pronouncing only the red onomatopoeia

(No gesture allowed!)





Exercise 2: vocal sketching

Why?

Trying different kinds of sonification

Example

Concept: find a good sound to help a visually impaired person searching for objects in the near field

Where is the key?

Exercise 2: vocal sketching

Why?
Trying different kinds of sonification

Example

Concept: find a good sound to help a visually impaired person searching for objects in the near field

Where are the marker pen and the scissors?

Sound synthesis: basics

Additive synthesis

Fourier decomposition:
sound = sum of harmonics (partials)

Frequencies and amplitudes
of each partials determine the timbre
=> reproducing an instrument

$$y[n] = \sum_{k=1}^{K} r_k[n] \cos(\theta_k[n])$$

FM synthesis

Frequency Modulation

Frequence of simple sine wave signal (**carrier**) is modulated by another sine wave signal (**modulating**)

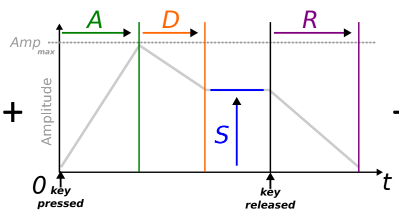
John Chowning [1973]

$$y(t) = \sin\left(2\pi f_p \cdot t + I_m \sin\left(2\pi f_m \cdot t\right)\right)$$

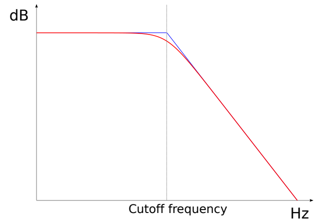
Sound synthesis: basics

Substractive synthesis

+



+



=

(With varying f_c)

Amplitude envelope
(ADSR: attack, decay, sustain, release)

Frequency filter

Sound synthesis: physically-based

Waveform of the sound to be generated is computed by using a mathematical model

Sound is produced/modeled according to physics, such as:

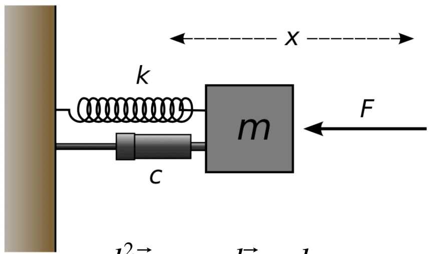
Force: $F = m \times a$

Position: $\vec{r}(t) = (x(t), y(t), z(t))$

Velocity: position change rate: $\frac{d\vec{r}}{dt}$

Acceleration: velocity change rate: $\frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}$

Examples:
spring-damper-mass sys



$$\frac{d^2\vec{r}}{dt^2} + \frac{c}{m}\frac{d\vec{r}}{dt} + \frac{k}{m}\vec{r} = 0$$

Sound synthesis: physically-based

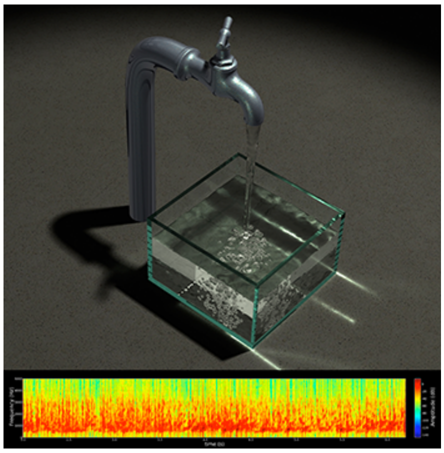
Contact sounds

Glass-like Wood-like

Rolling sounds

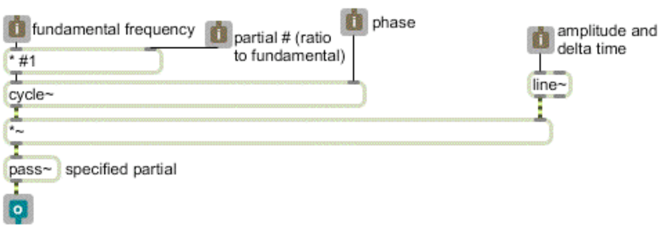
Fluid sounds

Notion of level of details
Sound "cartoonification"



Max/MSP

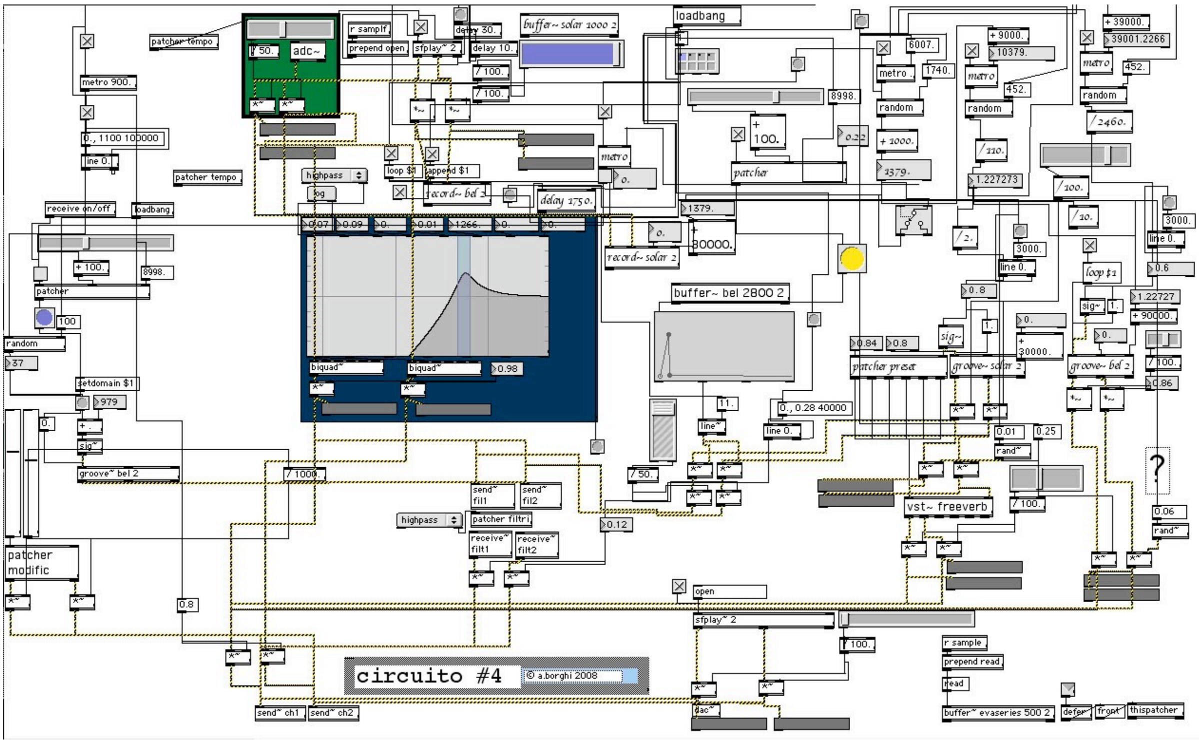
Real-time **graphical programming** environment
for audio, video, and graphical processing



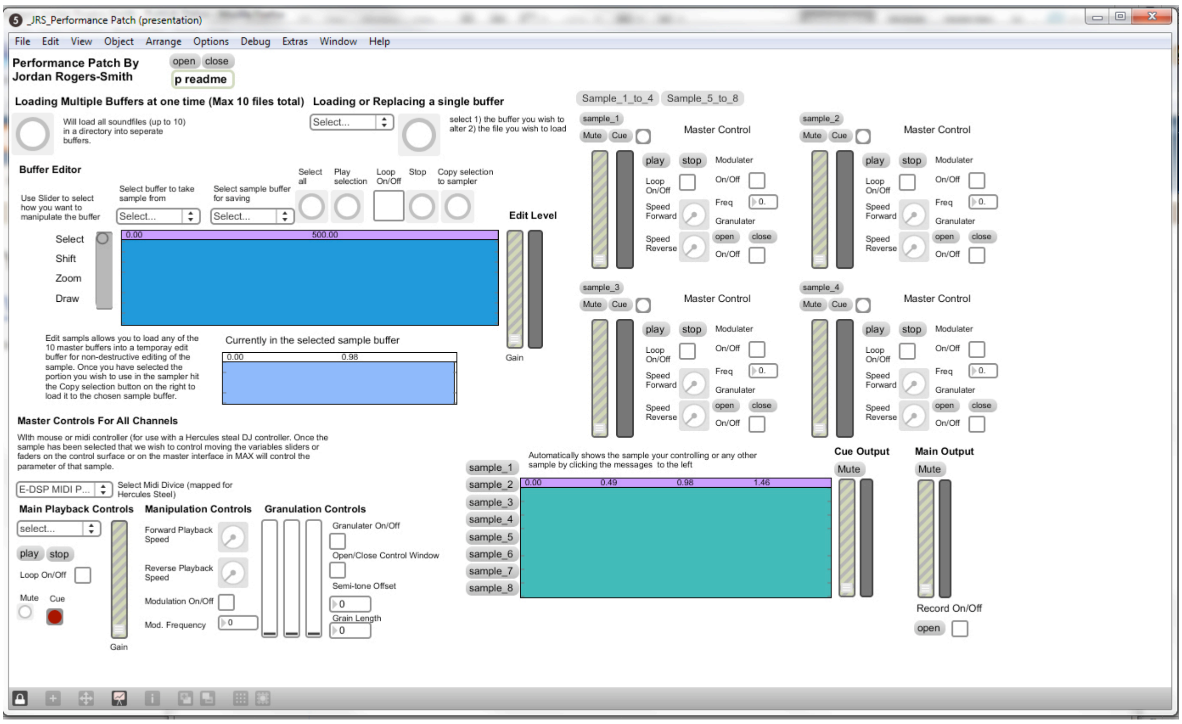
Started by IRCAM (~80's)
Now: maintained by Cycling'74 (http://cycling74.com/)
+ community
Commercial licensing

Mac OS-X / Microsoft Windows platforms only

Max/MSP



Max/MSP



Pure data (Pd)

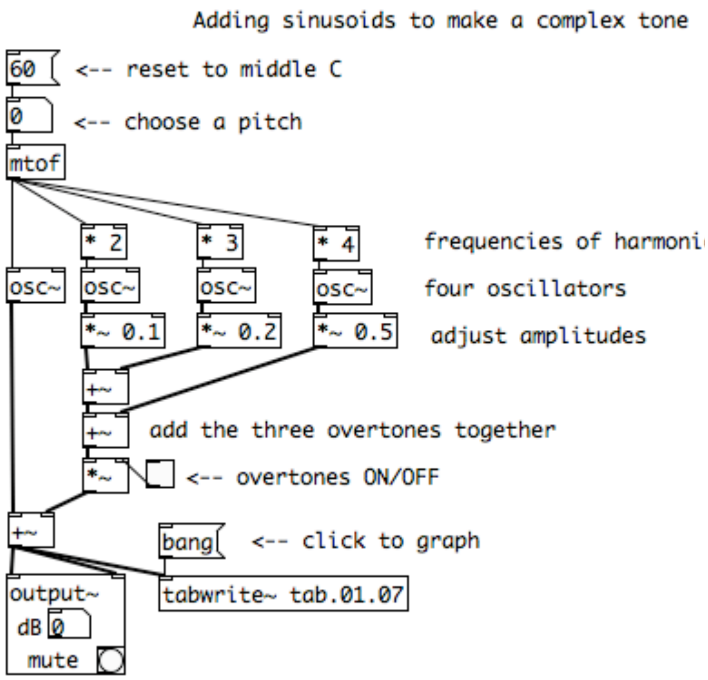
Multi-platform
real-time **visual programming** environment
for audio and video generation, and interaction with sensors

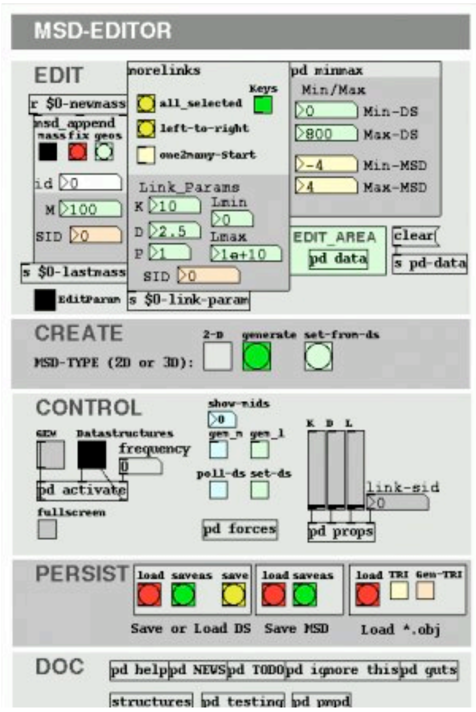
http://puredata.info/

Started by Miller Puckette (UCSD, IRCAM)
Now: community work

Compatibility between Max/MSP and Pd: **Flext** or **cyclone**

Pure data (Pd)





SuperCollider

Multiplatform **dynamic programming language** for **real-time** audio synthesis and algorithmic composition

http://supercollider.sourceforge.net/

Started by James McCartney in 1996
now: open source project (GPL)
maintained / developed by various people

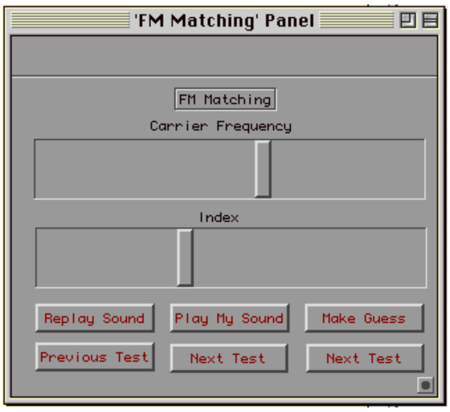
Can also be used for live coding performances
(programming on the fly during a performance)

SuperCollider

Example of code Babbling brook

```
{ ({RHPF.ar(OnePole.ar(BrownNoise.ar, 0.99), LPF.ar(BrownNoise.ar, 14)
* 400 + 500, 0.03, 0.003)}!2)
+ ({RHPF.ar(OnePole.ar(BrownNoise.ar, 0.99), LPF.ar(BrownNoise.ar, 20)
* 800
+ 1000, 0.03, 0.005)}!2)
* 4
}.play
```

Example of GUI:



Audio examples

Several audio examples on:
http://supercollider.sourceforge.net/audiocode-examples/

Csound

Multiplatform
programming language for sound written in C

http://www.csounds.com/

Started in 1984 by Barry L. Vercoe (MIT)
Now: GPL licence

No GUI interface

Also used for live coding performances

Csound and Python example

```
from Csound import *

"""
A Python function can use the CSD and instruments instances as arguments.
The way that the notes are produced – varying the duration and amplitude –
can also be part of the function.
"""
def motif(csd, instrument, start, note_length, amplitude=.5):
     time = start
     for note in 'C4 D4 D#4 F4 G4 D#4 C4 D4 F4 G#4 G4 D4 C4'.split():
          csd.score(instrument.note(time, note_length, note, amplitude))
          time += note_length return time

# Create the CSD and instruments as usual
csd = CSD('example_9.csd')
oscillator = oscil()
buzzer = buzz()
voice = fmvoice()
csd.orchestra(oscillator, buzzer, voice)

# Now add notes to the score using the function
motif(csd, buzzer, 0, .2, .25)
csd.output()
```