

Building Large-scale Interactive Systems with OSC, Siren, CSL, and CRAM

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(CREATE)

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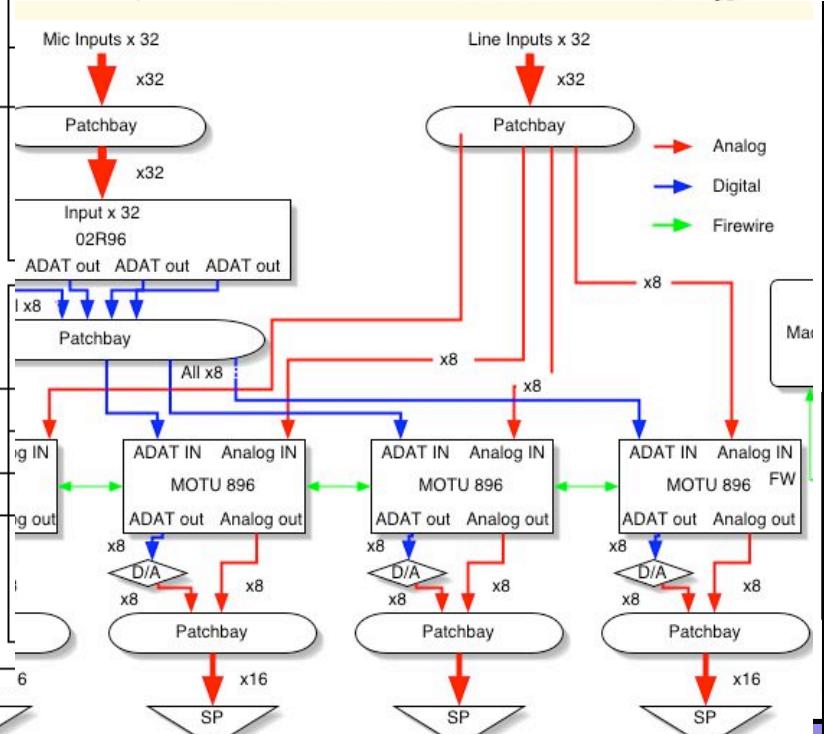
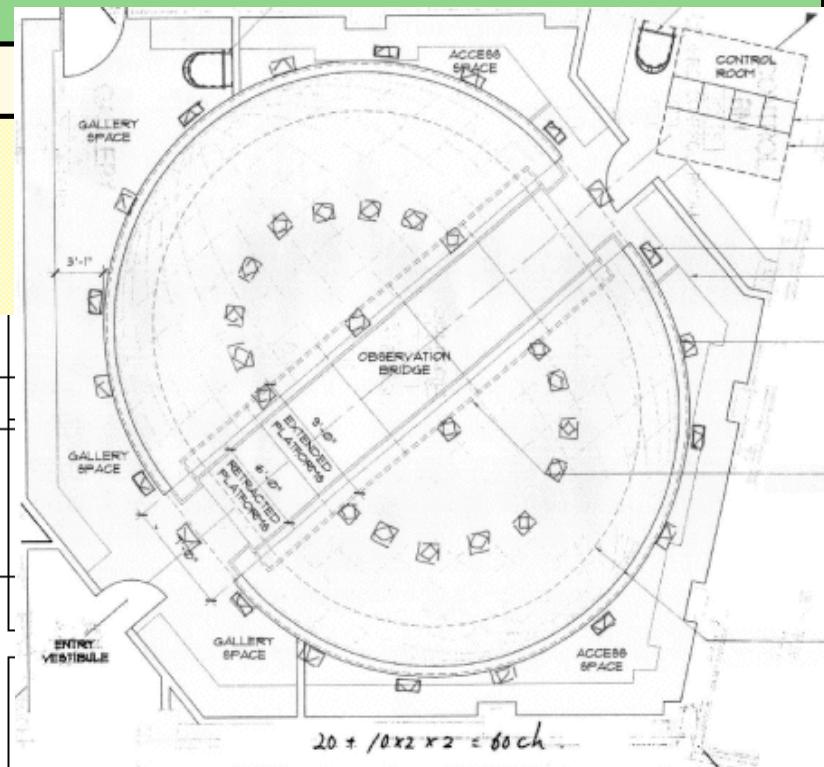
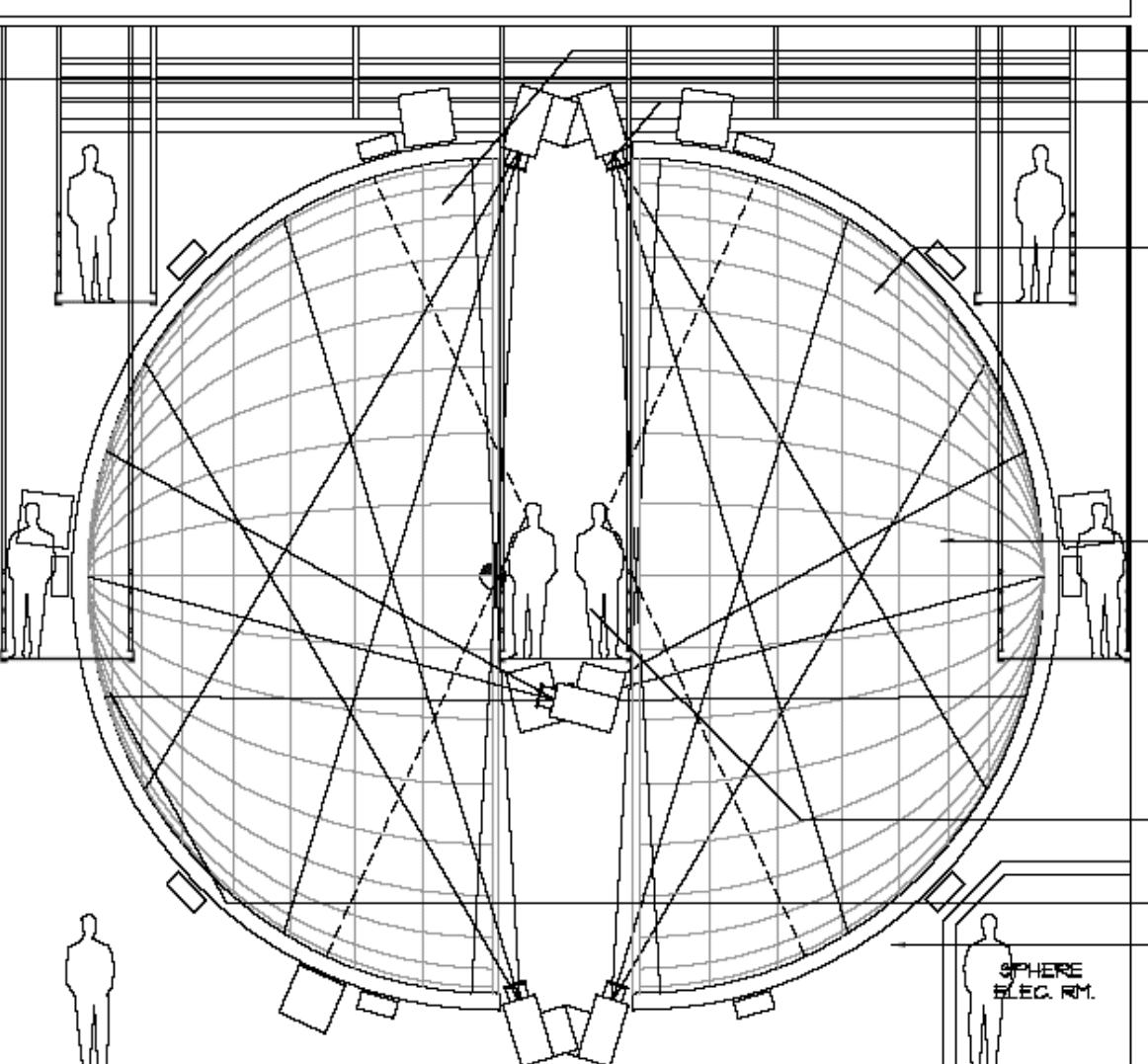
HW/SW Components

- **Siren:** Hierarchical / procedural representation for composers (OSC out)
- **CSL:** Scalable DSP framework (OSC srv)
- **CRAM:** Cluster management for distributed RT OO software (Mgr)
- **CNSI Sphere:** A really cool loud / bright / sensing space to play in!

Cal. NanoSystems Inst. @ UCSB

- MAT in CNSI: labs, studios, workshops, sphere
- CNSI compute infrastructure
 - Traditional vector supercomputer
 - 1024-node Linux cluster
 - Multimedia processing cluster (TBD)
- Sphere: 3-story I/O space
 - 12-channel overlapping video output
 - 128-channel sound output
 - Camera/microphone/sensor multi-modal input

CNSI Sphere



CREATE

How? DSCP!

Distr. Sys. Mgmt.
Fault-tolerance,
Load-balancing,

Distributed Sensing, Computation,
and Projection = MVC on steroids

Back-end application models are
scientific/numerical/simulation

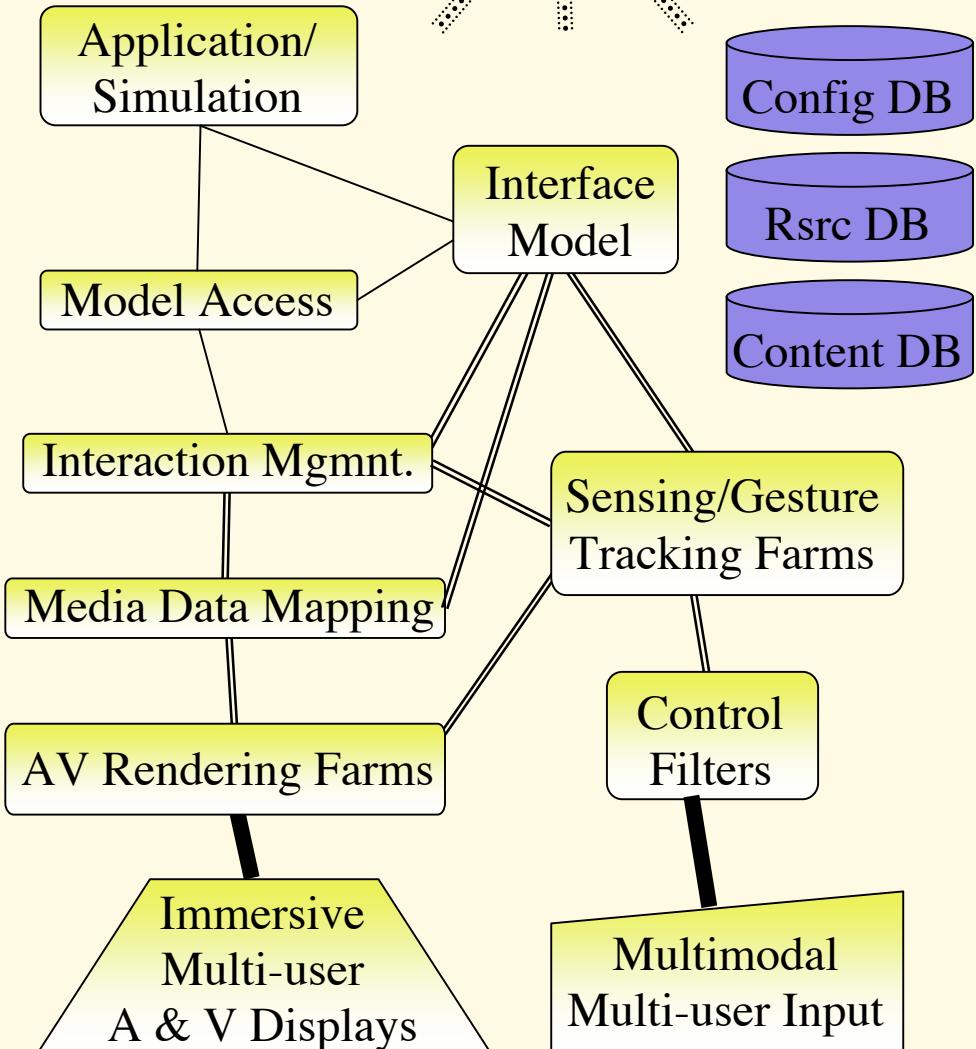
Multimodal multiuser **sensing/control**
and tracking/mapping farms

Application = sensing/tracking
policies + output data mappings

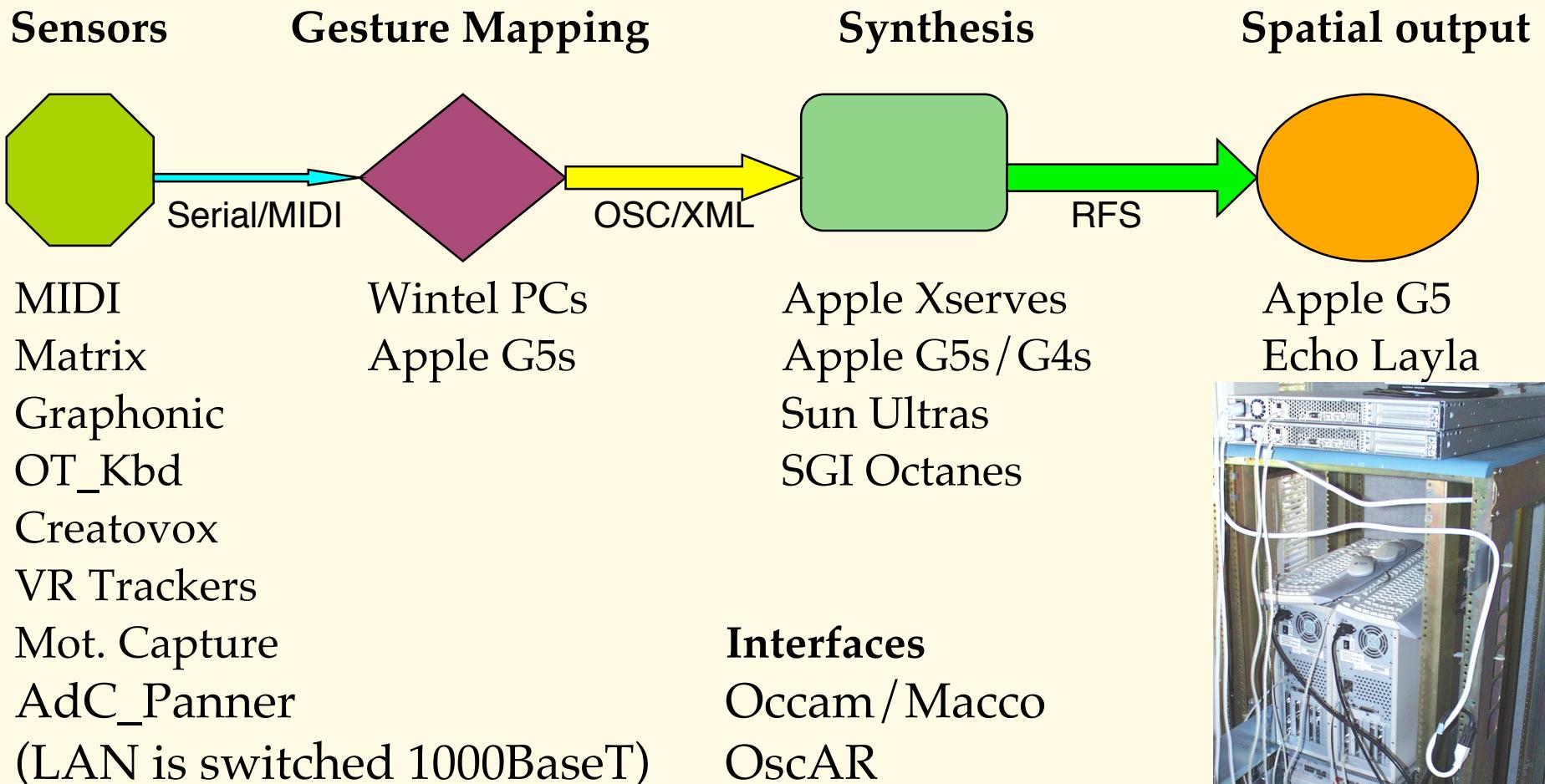
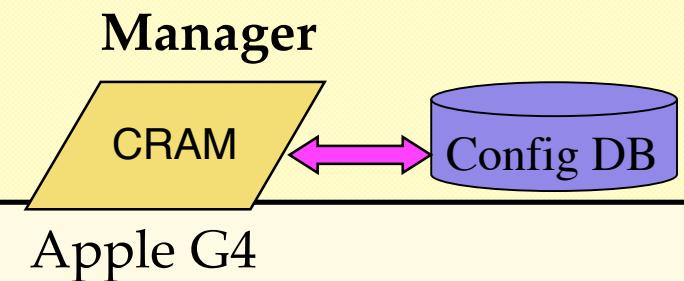
Presentation/interaction via CNSI
Sphere, LAN/WAN streaming

Infrastructure uses CRAM mgmnt

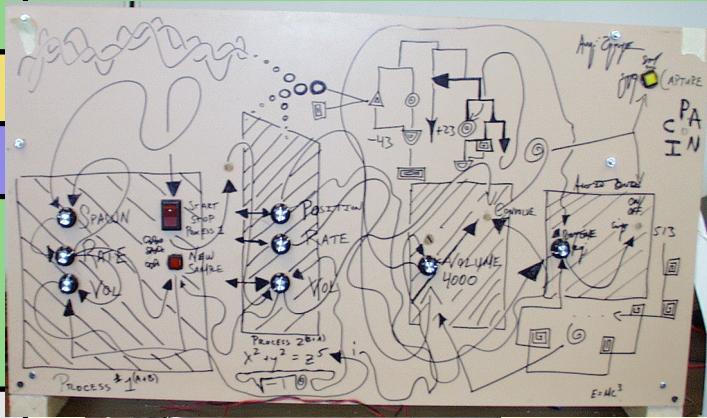
DBs for configurations, resources, and
media content (renderers)



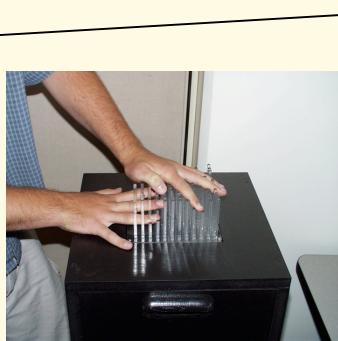
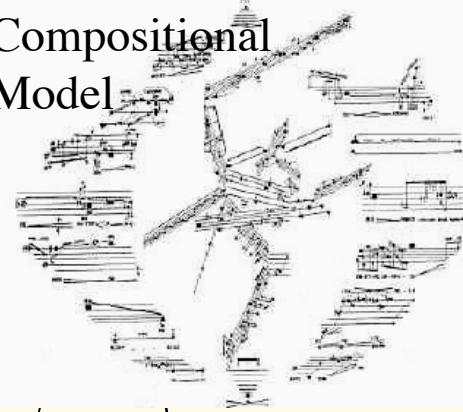
Current Sphere-lite



In Pictures

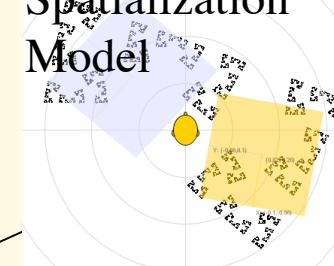


Compositional Model



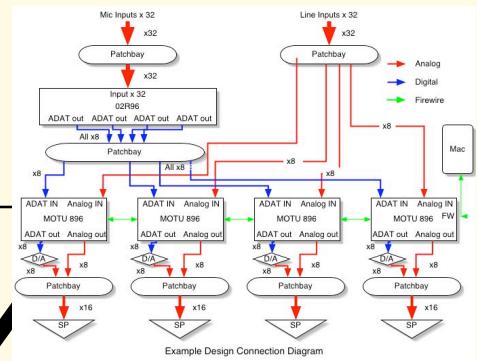
Gesture Sensors

Spatialization Model

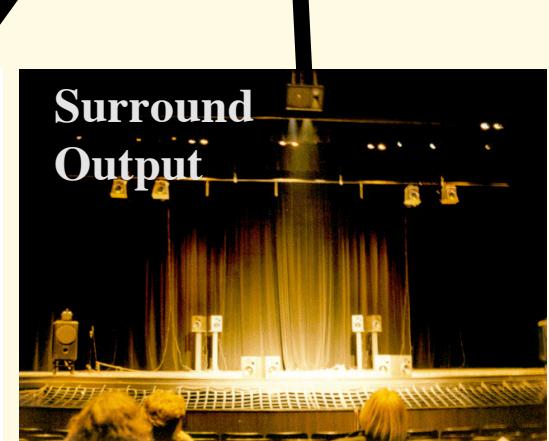


CSL
Server Farm

Output
Drivers



Surround
Output

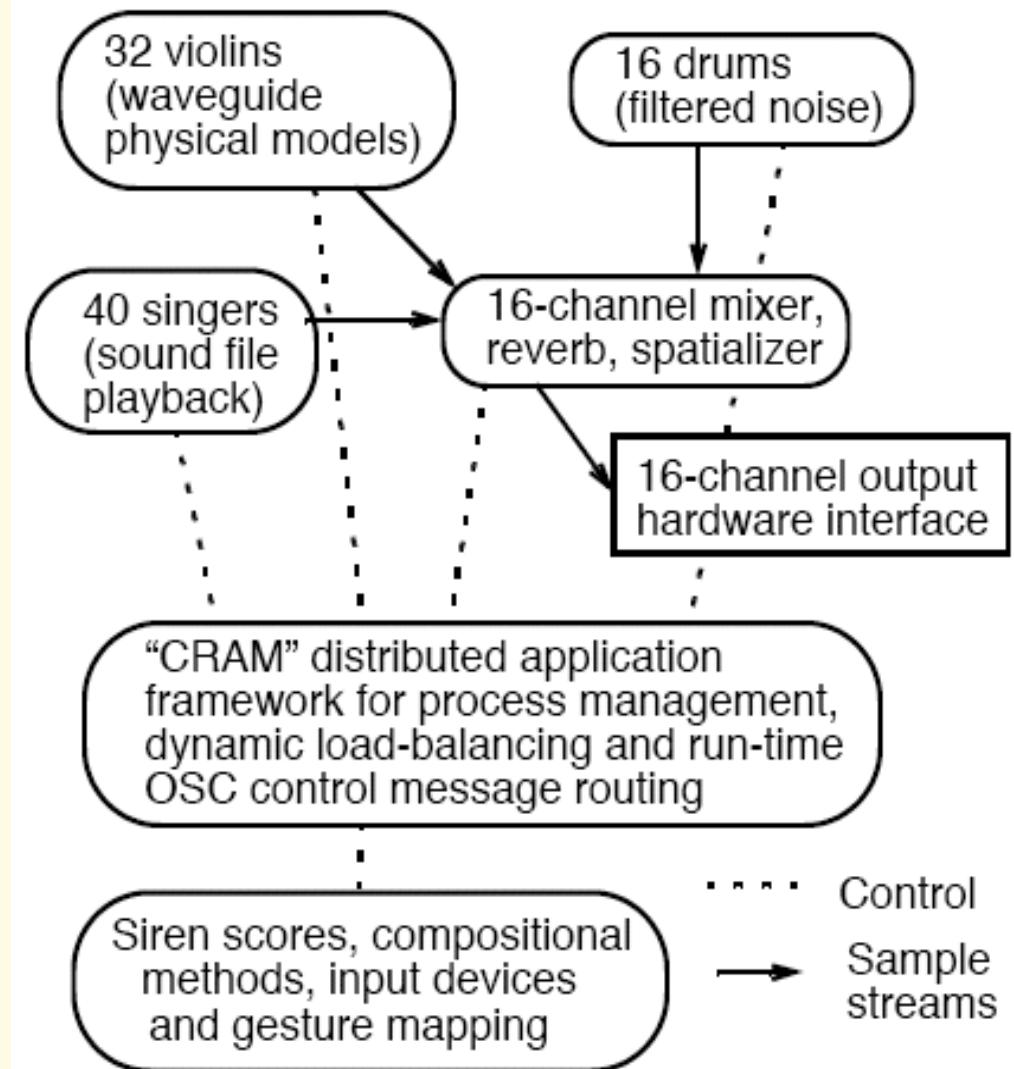


CREATE

MAT Media Arts and Technology Graduate Program

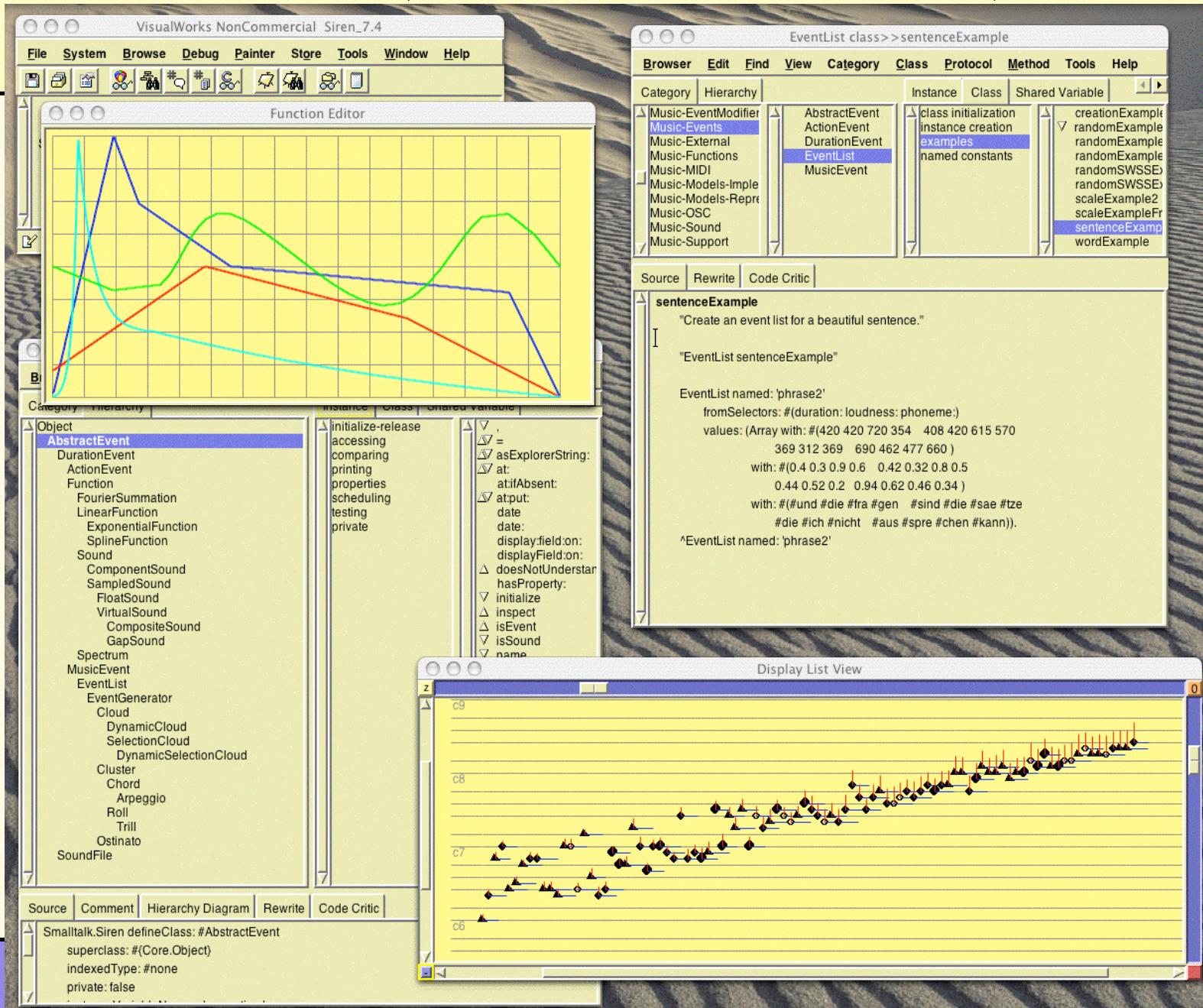
Networked Synthesis/Performance

- Managed “orchestra-scale” sound synthesis, multi-modal gestural sensing and control, and pluriphonic projection (up to 128 channel output in the CNSI sphere)



Siren 2003 (VisualWorks)

Demo



Demo

CSL “Hello world” Program

Sine wave with envelope

```
// Create a sine oscillator -- this is a comment
```

```
    Sine osc(220.0);
```

```
// Create an ADSR envelope -- args are (dur, a, d, s, r)
```

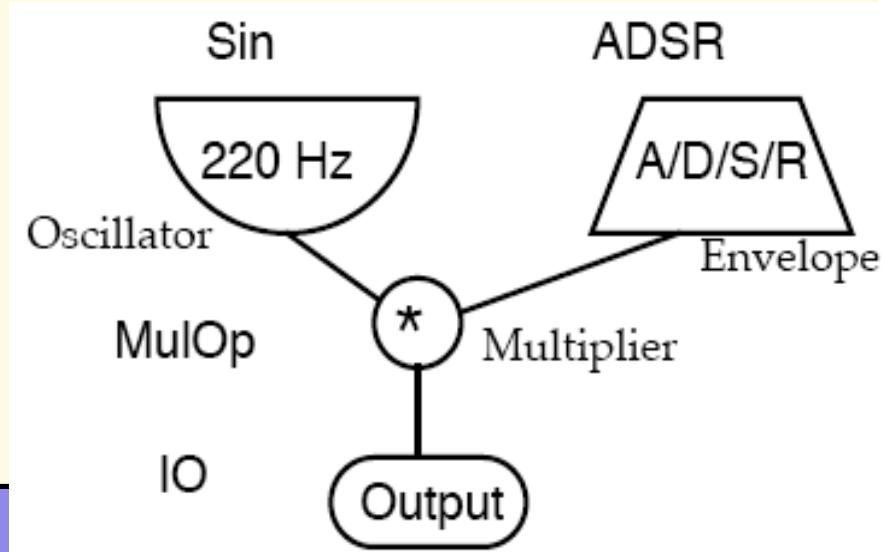
```
    ADSR env(3.0, 0.06, 0.2, 0.2, 1.5);
```

```
// Create a multiplier
```

```
    MulOp mul(osc, env);
```

```
// Plug it into the output driver
```

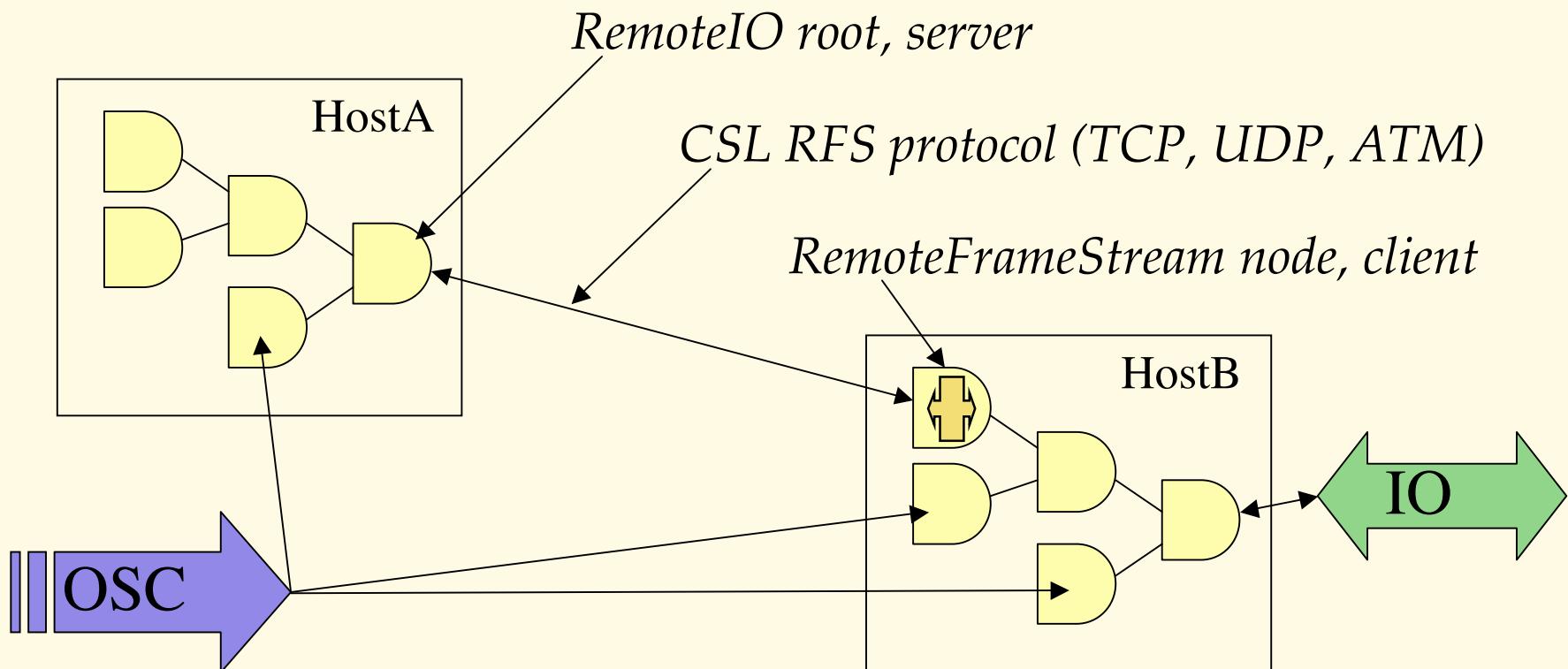
```
    globalIO.set_root(mul);
```



Demo

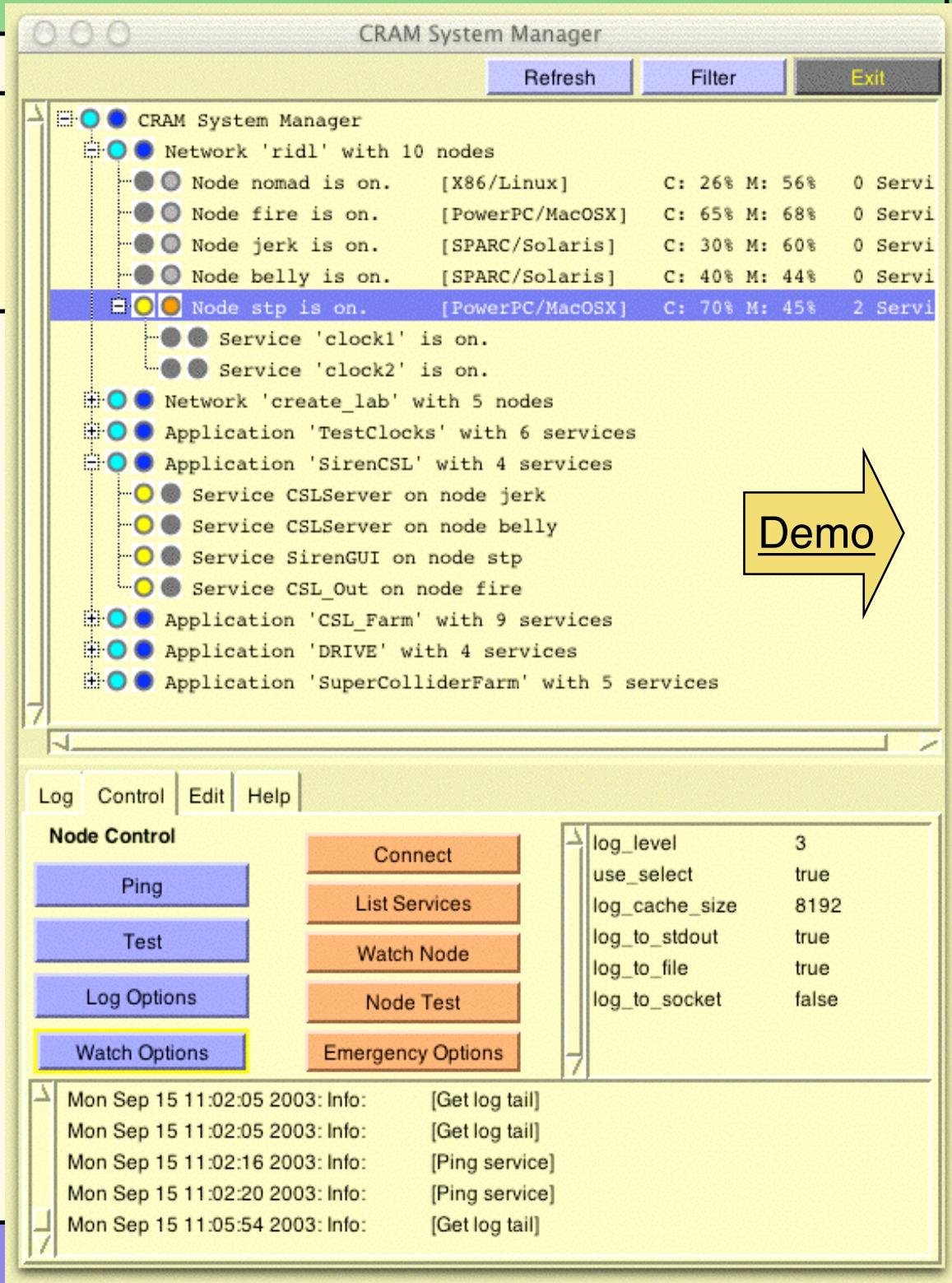
Multi-host CSL Graphs

- Distributed sub-graph processing with RemoteIO and RemoteFrameStream, RFS protocol, buffering



CRAM Manager

- Network/Node
- Node/Service
- Application/Service
- Log/Control pane
 - Run-time monitor
 - Planning
 - DB play-back



GestureSensor Drivers & Servers

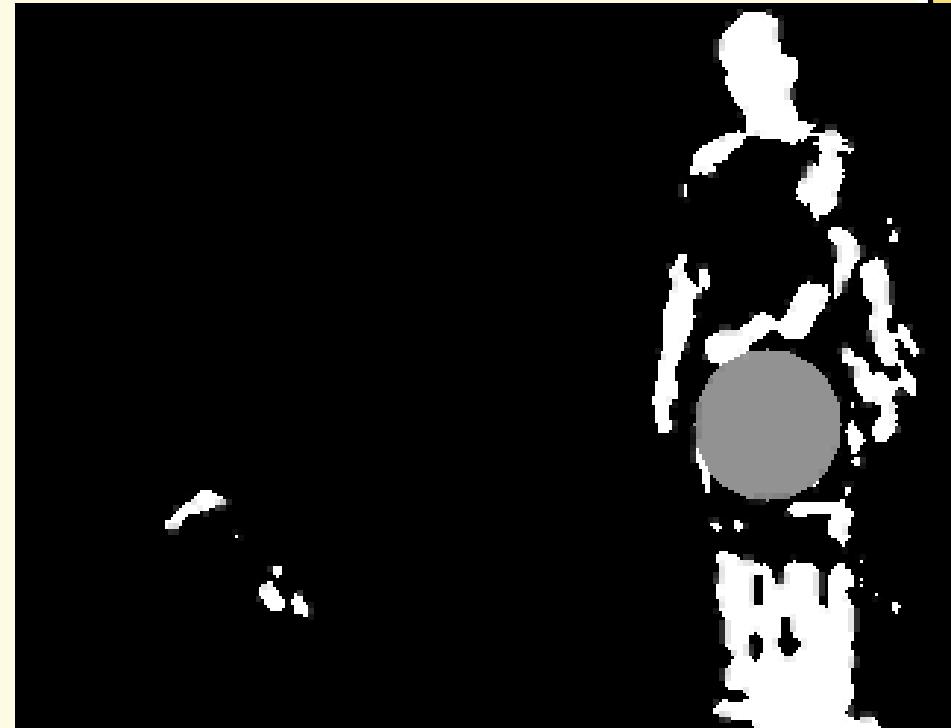
- Reusable sensor driver framework
 - Serial in, cacheing / differencing / throttling, OSC out
- GestureSensors: receive OSC or MIDI

```
void * mData;           // data array (typically a float *)
char * mCmd;             // OSC command (without the '/')
char * mTypeString;      // OSC type string, e.g., "ffff"
```

 - Event input thread mgmnt
 - Parsing and differencing
 - Map to static or global data or messages
- Subclasses
 - Glove, Ebeam, Matrix, FOBirds, AdC_Panner, etc.

CV-to-OSC

- Multiple-camera 3D motion tracking of multiple sources
- Data mapping for sound synthesis and transformation algorithms
- Intelligent trans-media system that learns and adapts, based on memory of the actions and states of the sensor space



Siren (MODE, HSTK, DoubleTalk)

- Smalltalk-based object-oriented framework for sound / music description and processing, under development since 1984
- Focus on structure representation, control mapping, and composition, rather than on performance, DSP, or notation
- API / Platform for music representation and composition language development

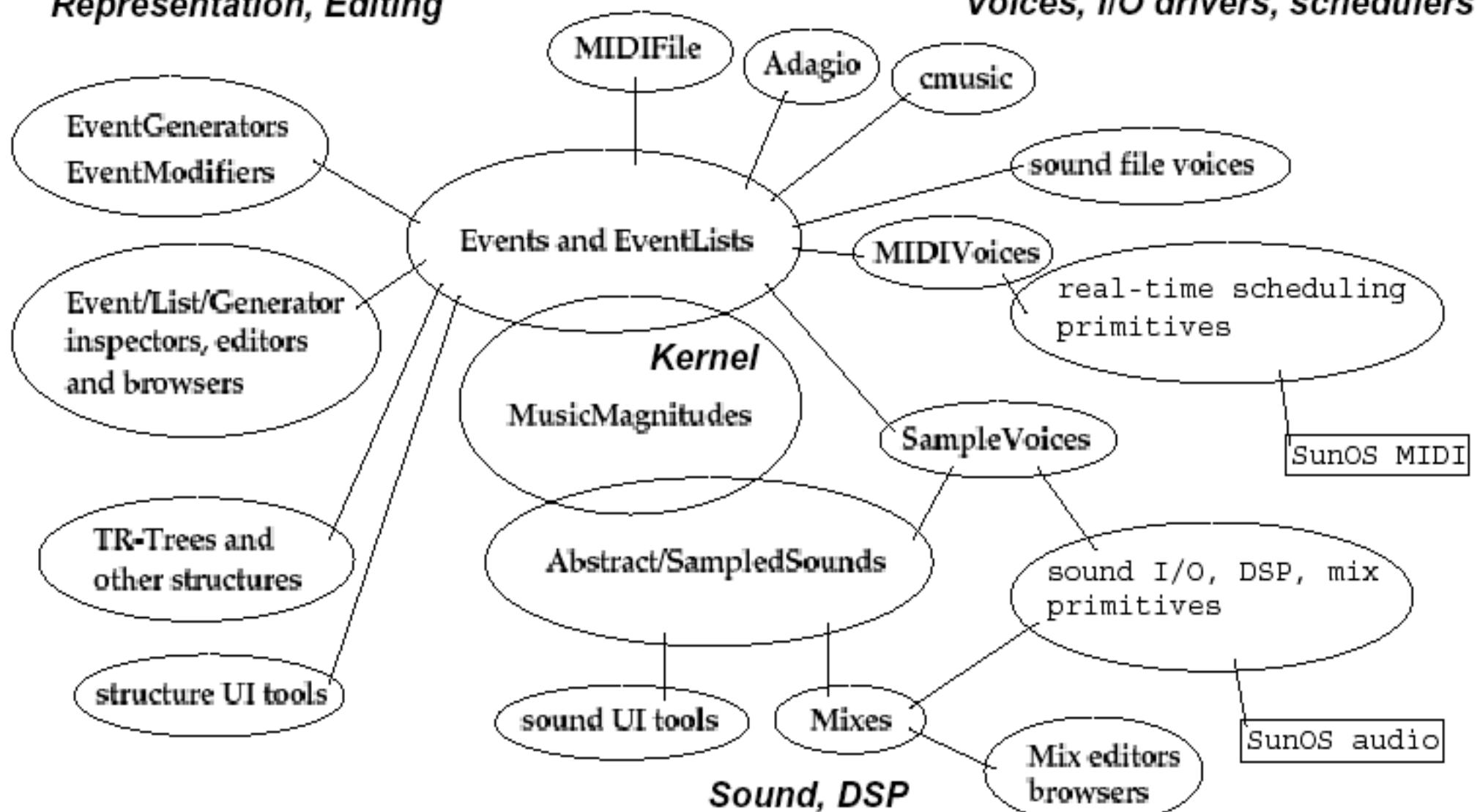
What's Siren?

[440 Hz, (1/4 beat), 44 dB]
evtList mapPitches: gamut.
evtList playOn: Voice default.

- **Smoke** music representation language
 - Music magnitudes, events, event lists, generators, modifiers, struct. algorithms, ...
 - Organize timing, tuning, timbre, space, gesture, grouping, versioning
- **I/O voices** (players, property-parameter mappers) for many formats: (m11-SC3) note lists, OSC, MIDI, XML, CORBA, ...
- Multi-threaded RT **scheduler**
- GUI **widgets** and apps for music
- (OO/R)DBMS interfaces for **persistence**

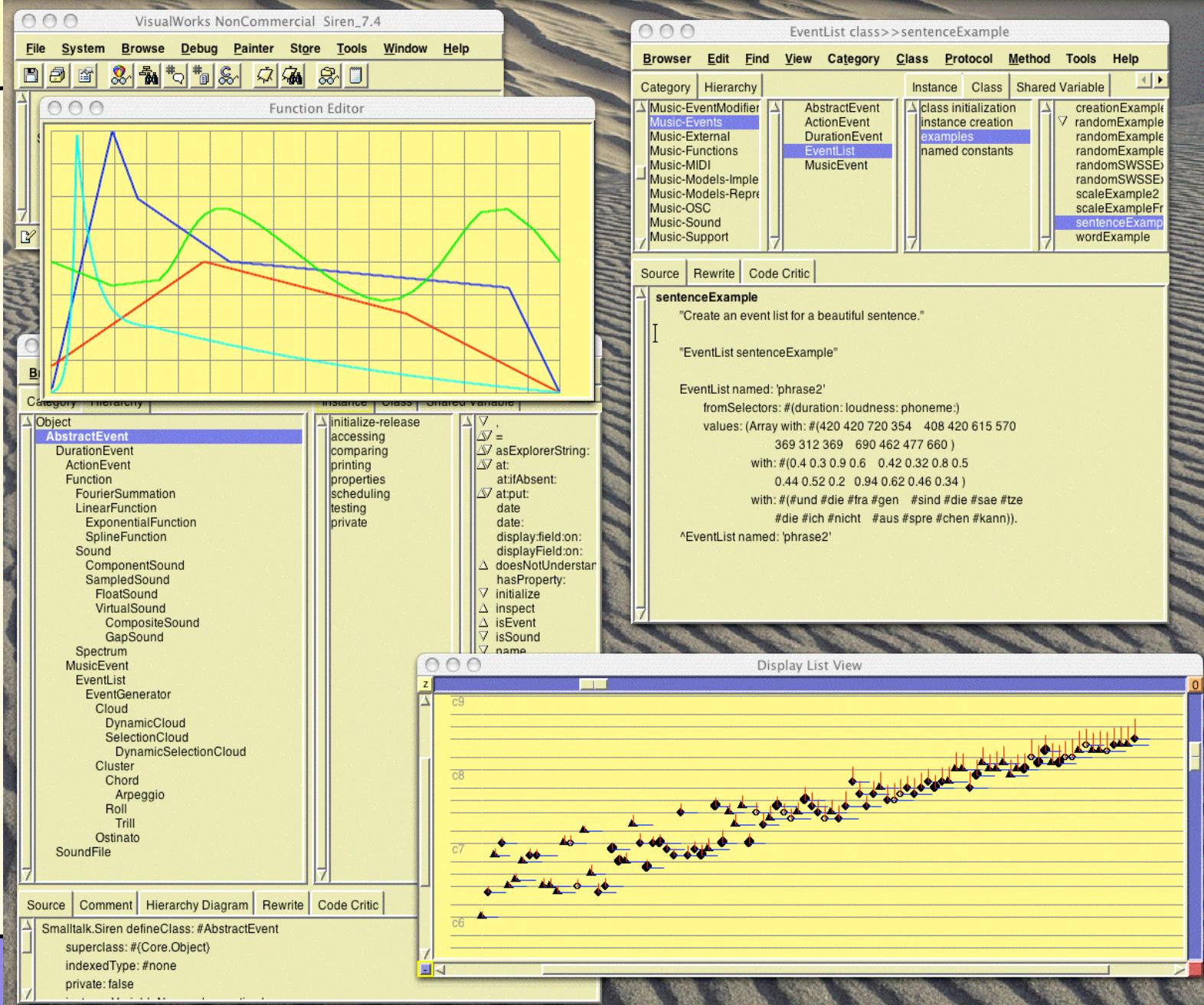
Siren Components (1992)

Representation, Editing



Siren 2003 (VisualWorks)

Demo



Siren Tools 1984-2004

PrjNetEditor

FileOperations

- Predicates
- Transition
- Edges

Subset

EditorView

Editors

Check

SubNet

newNet3

MarkingEditor

SimulationEditor

- Inspect
- FormularEditor
- AnalyticsEditor

Initial Marking of newNet3

Form Type Definition Editor

Formular - Daten - Verkund

MODE Mix View

Play **File** **Edit** **Inspect** **Add** **Zoom** **Properties**

yl.4b2.snd
yl.2a2.snd
yl.2b1.snd
yl.4a1.snd
yl.2b2b.snd
yl.2b2.snd
yl.4a3b.snd
yl.2b2b.snd
yl.2c4.snd
yl.4b2.snd
yl.2c4.snd
yl.4b2.snd
yl.2c4.snd
yl.4a3b.snd
yl.2c2a.snd
yl.2b2b.snd

redraw
sort
add
cut
copy
paste

CREATE

Motors 003B **ThingLab** **Play With Me - 3** **Squeak Launcher**

Sound View on: unbekannt.mrd

Siren

Introduction to Siren
Siren Set-up
The Siren Design
The Siren Model Representation
Music Magnitude Models
Siren/Sound Events
Predicates and Event Hierarchy
Siren Functions
MIDI and Sound Schedulers
Scheduling and Performance
Voices, Ports, and Event I/O
About MIDI

The Siren system is a general-purpose music and sound composition, processing, performance, and analysis system; it is a component of the Motive Object-Oriented Environment (MOOE), the software component of the Motive Interactions project. Siren is a collection of about 200 Smalltalk classes for building musical applications; the current version works on Squeak 2.3 running on Mac, Windows, and SGI systems with MIDI drivers and CD-quality stereo audio I/O. The Siren release is available via anonymous Internet Itp

Sound Browser on /usr/stp/snd

Sound **Play/Stop** **File** **Inspect**

Music Model Hierarchy

MusicMagnitude
ConditionalDuration
SymbolicLoudest
SymbolicPitch
Print
MusicModel
Lyric
Amplitude
portus
Strettonization
Directionality
Chroma
Pitch
OctaveNumber
Chorus
Duration
Metre
NormalMagnitude
BurstPitch
SecondDuration
Intensity
MIDIVelocity
MIDIPitch
Performance
RestDuration

General MM Instruments

Flute	Organ	Bass	Ensemble	Reeds	Synth Lead	Synth Effect	Percussion
alto	perc	cello	drum	sax	lead 1	drum	triangle
bassoon	organ	double bass	drumset	trumpet	drum 2	glockens	agogo
clarinet	perc	drum	drumset	trumpet	drum 3	bell	hand bell
clarinett	organ	drum	drumset	trumpet	drum 4	chimes	hand chime
drum	perc	drum	drumset	trumpet	drum 5	glockens	woodblock
drumset	organ	drum	drumset	trumpet	drum 6	chimes	woodchime
drums	perc	drum	drumset	trumpet	drum 7	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 8	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 9	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 10	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 11	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 12	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 13	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 14	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 15	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 16	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 17	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 18	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 19	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 20	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 21	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 22	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 23	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 24	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 25	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 26	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 27	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 28	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 29	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 30	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 31	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 32	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 33	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 34	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 35	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 36	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 37	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 38	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 39	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 40	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 41	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 42	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 43	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 44	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 45	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 46	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 47	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 48	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 49	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 50	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 51	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 52	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 53	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 54	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 55	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 56	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 57	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 58	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 59	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 60	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 61	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 62	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 63	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 64	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 65	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 66	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 67	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 68	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 69	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 70	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 71	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 72	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 73	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 74	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 75	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 76	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 77	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 78	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 79	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 80	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 81	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 82	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 83	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 84	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 85	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 86	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 87	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 88	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 89	chimes	woodchime
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drumset	perc	drum	drumset	trumpet	drum 91	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 92	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 93	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 94	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 95	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 96	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 97	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 98	chimes	woodchime
drumset	perc	drum	drumset	trumpet	drum 99	chimes	woodchime
drumset	organ	drum	drumset	trumpet	drum 100	chimes	woodchime

Function Editor

"a low/rising crescendo cloud"

(DynamicPodCloud dur: 6
pitch: #(39 to: 54) (72 to: 72) "starting/ending pitch ranges"
amp: #(49 to: 60) (80 to: 120) "and amplitude ranges"
voice: (1 to: 2) "static voice selection range!"
density: 20) "rate per second"

LPC Frame Data from ywe_shr_3c1.lpc

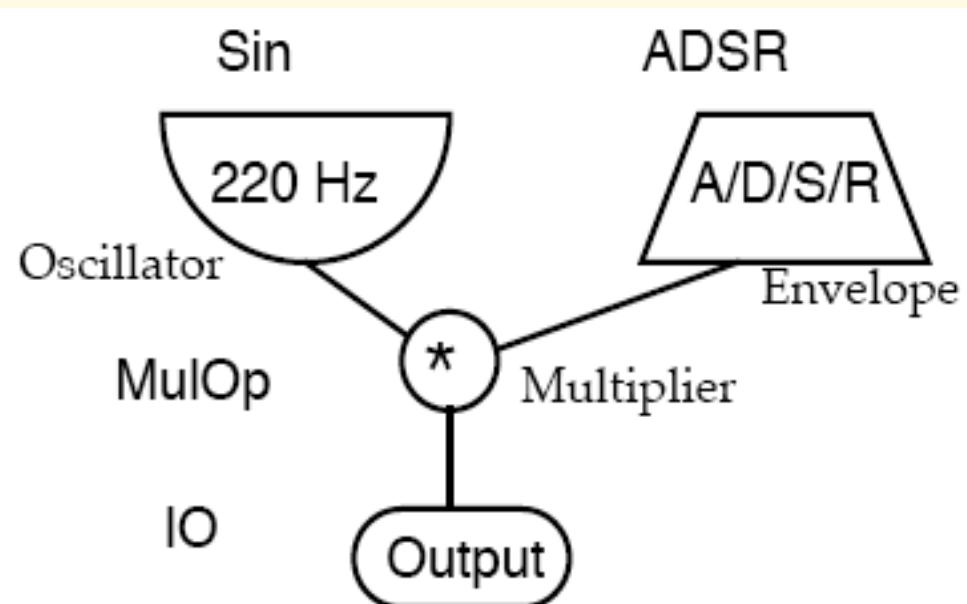
Hauer-Steffens Event List View on m2.b1a.sc

Mode T-R Tree Browser on: Vwe Ve, Vi Jr D!

The CREATE Signal Library (CSL, “sizzle”) (“chill?”)

Demo

- General-purpose, portable C++ framework for distributed, real-time digital audio synthesis and processing
- Used for stand-alone applications, plug-ins, OSC servers, etc.



CSL Relatives

- Like Cmix, STK, Siren, JSyn, MxV, or CLM
 - Delivered as a library in a general-purpose programming language
- Unlike SuperCollider, Csound, Max
 - Not its own language
 - No scheduler
 - Uses C++ development environment

CSL3 Basics

- **Buffer** objects (1-4 classes)
 - Multichannel non-interleaved sample storage
 - “Smart” object, not just a (float **), ptr. mgmnt.
 - Handle malloc/ free, filling statistics, etc.
- **FrameStream** classes (Ugens) (many)
 - Respond to the message next_buffer(input, output)
 - Processors have a FrameStream as input
- **Mix-in** classes (vs. wrapper classes)
 - Phased, Positionable, Writeable, Cacheable, etc.

“Hello world” in CSL

Demo

Sine wave with envelope

```
// Create a sine oscillator -- this is a comment
```

```
    Sine osc(220.0);
```

```
// Create an ADSR envelope -- args are (dur, a, d, s, r)
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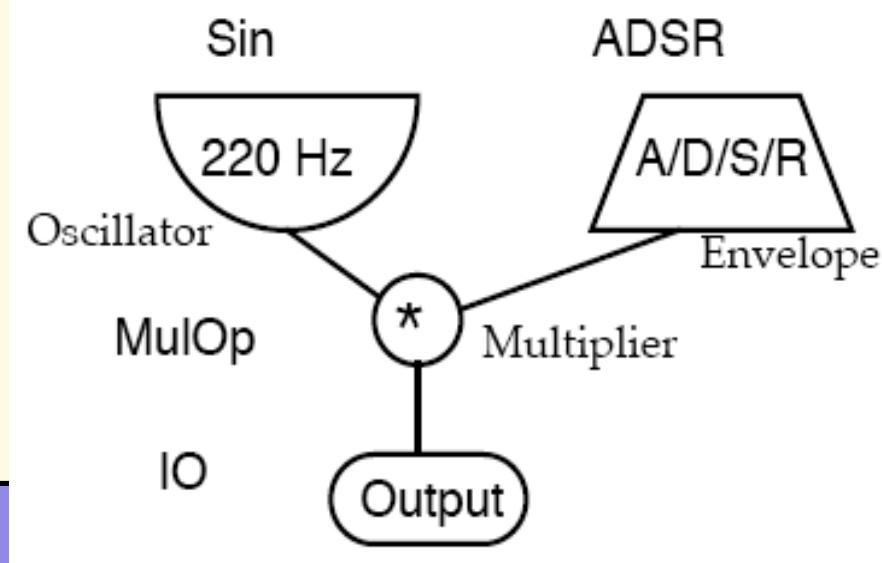
```
    ADSR env(3.0, 0.06, 0.2, 0.2, 1.5);
```

```
// Create a multiplier
```

```
    MulOp mul(osc, env);
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```
// Plug it into the output driver
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    globalIO.set_root(mul);
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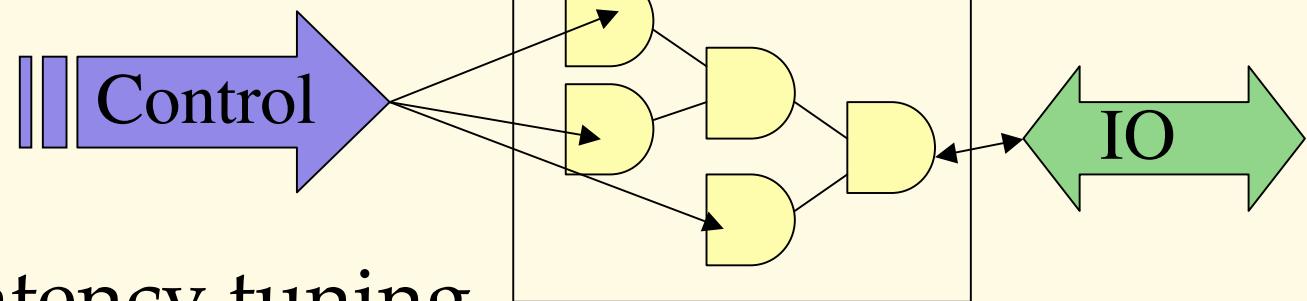
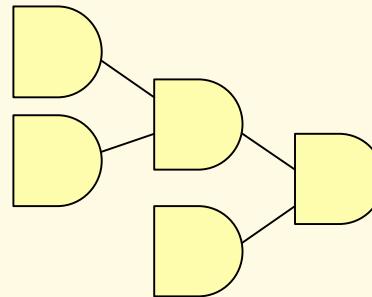


CSL Sources, Controls, and Processors

- **Sources**
 - Oscillators (perfect, BL), SumOfSines, Noise, SoundFiles, Chaotic/IteratedFS, IFFT, Physical Models, Granulators, Signal windows
- **Control**
 - Envelopes, LFOs, LFNoise, ProbDists, DynamicVariables, OSC, MIDI, GUI, CORBA, XML, note lists, Feature extractors, Input followers
- **Processors**
 - Operators, Mixers, Filters/banks, Reverbs, (N-M)Panners, DelayLines, FDN, WaveShape, Lo-latency Convolution, FFT/IFFT, LPC/FIR
- **Support**
 - RingBuffer, ThreadedFrameStream, BlockResizer, RateConvertor, Splitter/Joiner, FanOut (needed), Interleaver/Deint., Test main()s
 - Tools: FIR/Reverb IR Design, Spectrum DBs, Control-mapping

The Big Picture of CSL

- Basic DSP graph
- Connected to control input
(OSC, MIDI, GUI, CORBA, XML), and IO object
- Buffering and latency tuning



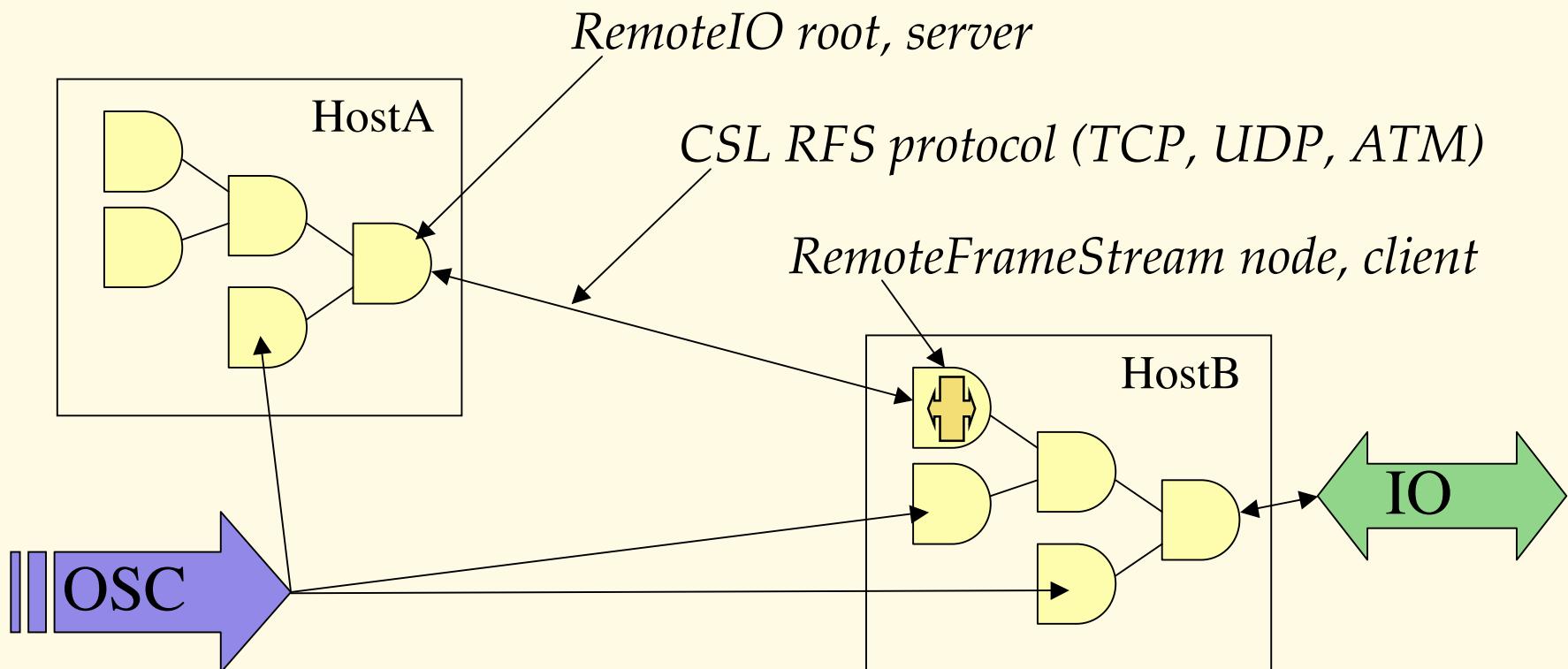
CSL DSP Graph Flexibility

- Sub-graphs can run at different:
 - Sample rates (for control),
 - Buffer sizes (for transforms),
 - Numbers of channels (for efficiency),
 - Buffer formats (interleaved or not),
 - In different threads, etc.
- These can be changed (within reason) at run-time (e.g., for load- or traffic-balancing)

Demo

Multi-host CSL Graphs

- Distributed sub-graph processing with RemoteIO and RemoteFrameStream, RFS protocol, buffering



Instruments and OSC/MIDI/XML

- Instrument object
 - Holds onto a DSP graph; adds “reflective” accessors
 - Generates OSC address spaces, MIDI maps, etc.
 - Server main() function loads an instrument library and publishes an address space on a listener socket

```
Example: // C++ accessor decl.  
list[0] = new Accessor("du", set_duration_f, CSL_FLOAT_TYPE);  
list[1] = new Accessor("am", set_amplitude_f, CSL_FLOAT_TYPE);  
// Produces:  
/i1/ instrument 1's OSC address space  
/i1/du: set-duration command  
/i1/am: set-amplitude command
```

GestureSensor Drivers & Servers

- Reusable sensor driver framework
 - Serial in, cacheing / differencing / throttling, OSC out
- GestureSensors: receive OSC or MIDI

```
void * mData;           // data array (typically a float *)
char * mCmd;             // OSC command (without the '/')
char * mTypeString;      // OSC type string, e.g., "ffff"
```

 - Event input thread mgmnt
 - Parsing and differencing
 - Map to static or global data or messages
- Subclasses
 - Glove, Ebeam, Matrix, FOBirds, AdC_Panner, etc.

CSL main() for OSC Processing

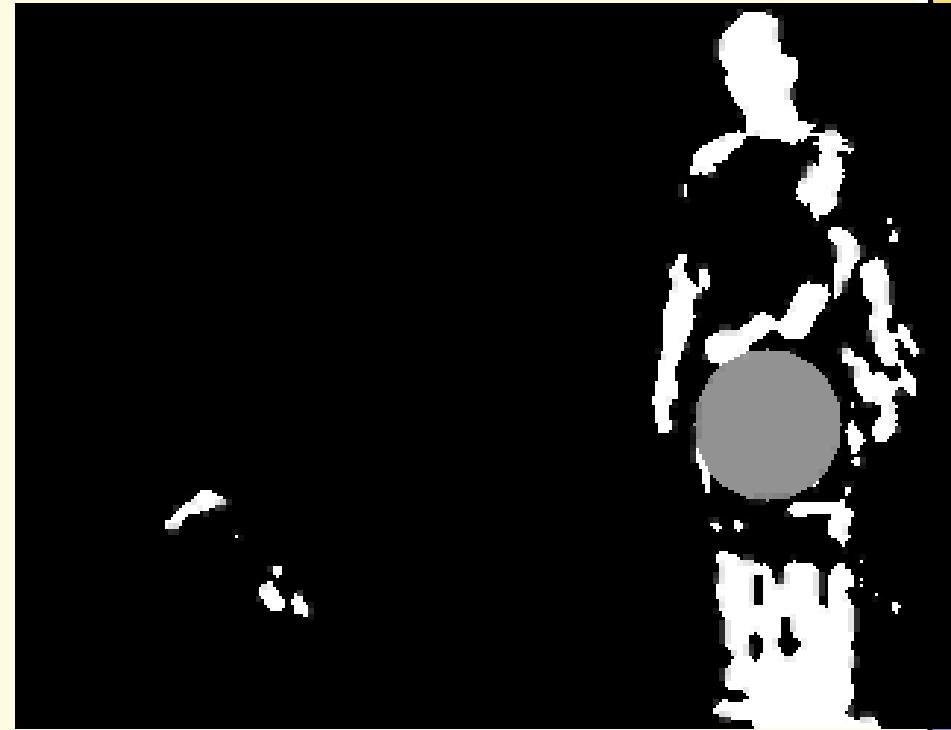
```
// Set up OSC address space root  
init_OSC_addr_space();  
// EITHER: add the instrument library OSC addr. space  
setup_OSC_instr_library(library, numInstruments);  
// OR: create a background thread for a GestureSensor  
Thread * aThread = ThreadPthread::MakeThread();  
aThread->fork_thread(GS_thread_fcn, & someArgument);  
// start the I/O callback thread  
GlobalIO->start();  
// Run the OSC I/O loop function (doesn't return)  
main_OSC_loop(theUDPPort);
```

OSC with a Shell Script

```
# Shell script to test sending OSC messages to CSL
# Create a convenient alias
alias ssoo "sendOSC -h localhost 54321"
# Play a note on instrument 1
ssoo /i1/p;      sleep 3
# Set a value and play another note
ssoo /i2/cf,50.0;  ssoo /i2/p;      sleep 3
# play a note with parameters: dur/amp/car/mod/ind
ssoo /i4/pn,4.0,0.3,220.0,357.4,3.0;  sleep 4
# load a sound file
ssoo /i8/fi,"$CSL_DATA/shine.snd"
# play a sampled sound
ssoo /i8/p;      sleep 1
```

CV Input to OSC

- Implement multiple camera 3D motion tracking of multiple sources.
- Construct an intelligent trans-media system that learns and adapts, based on memory of the actions and states of the sensor space.
- Map the data to sound synthesis and transformation algorithms that will provide evocative and meaningful results.

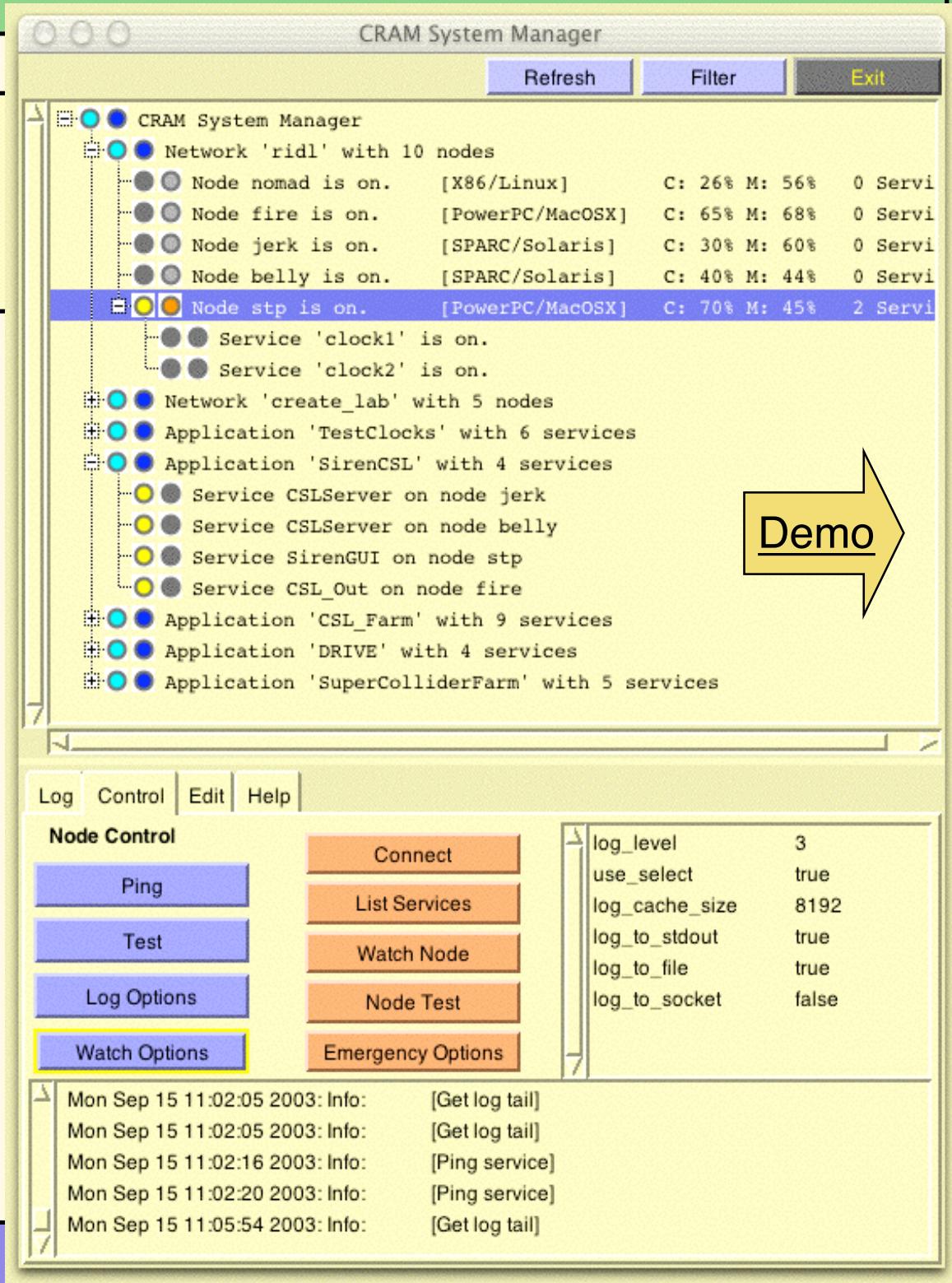


Managing Siren and CSL: CRAM

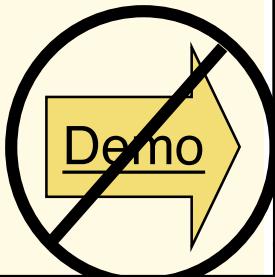
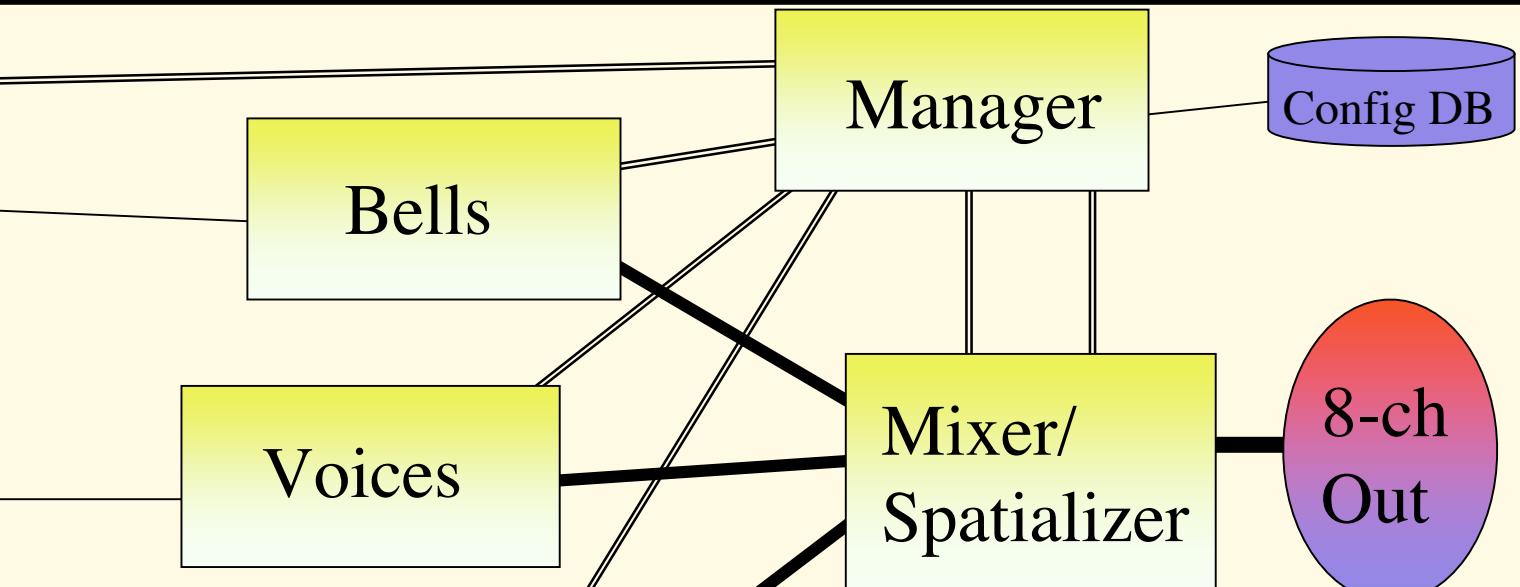
- CRAM: Yet another **Distributed Processing Environment** (DPE, Cluster Mgmt. literature)
- Framework to deploy, start/stop, and monitor multi-host distributed real-time OO applications
- Provides fault-tolerance and load-balancing*
- CRAM is 3rd-gen. DPE implementation at CREATE (1996-2004) (HPDM/TAO, Yellow/CORBA_AV)
- Designed for robustness, simplicity, and low overhead; limited services and scalability / replication

CRAM Manager

- Network/Node
- Node/Service
- Application/Service
- Log/Control pane
 - Run-time monitor
 - Planning
 - DB play-back

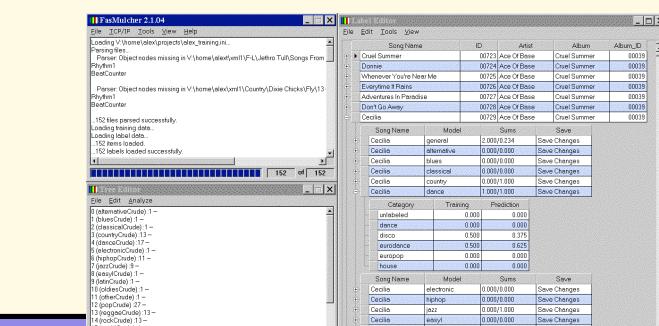
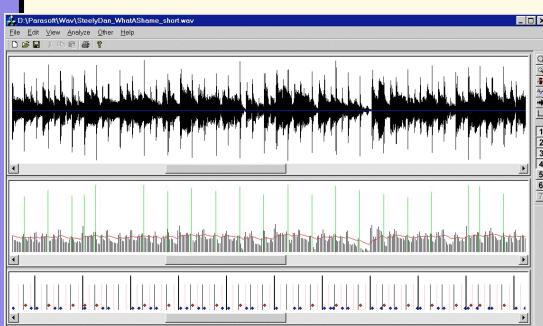
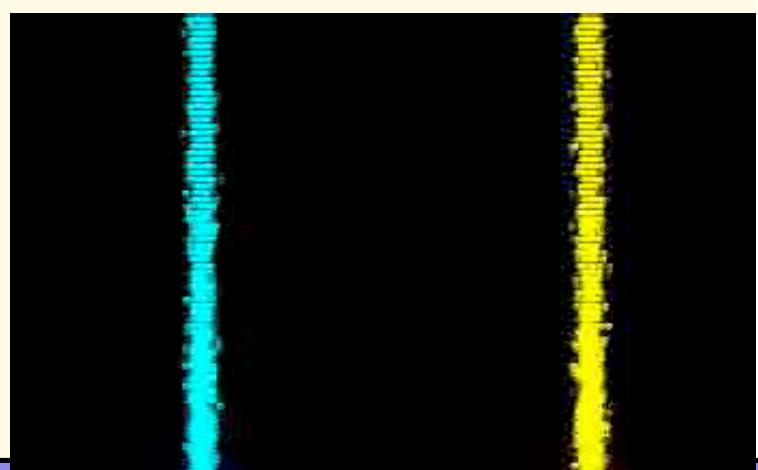
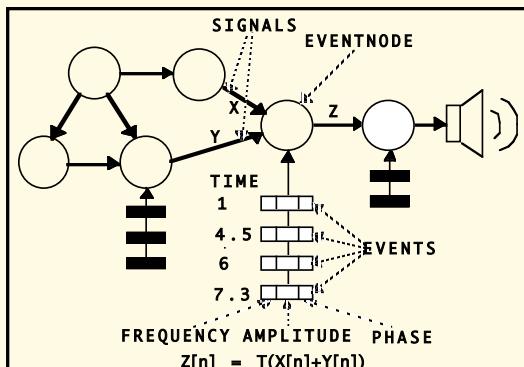
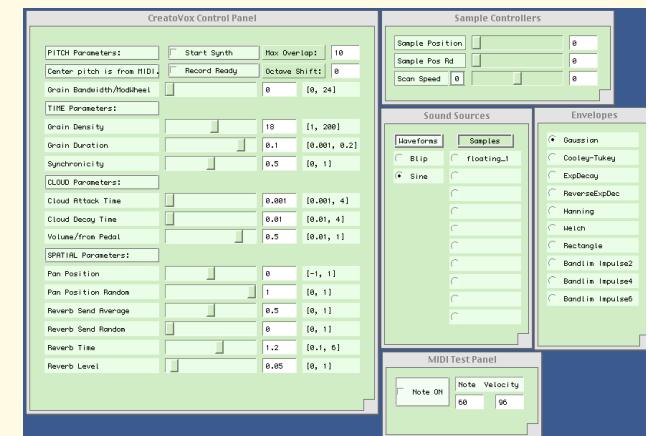
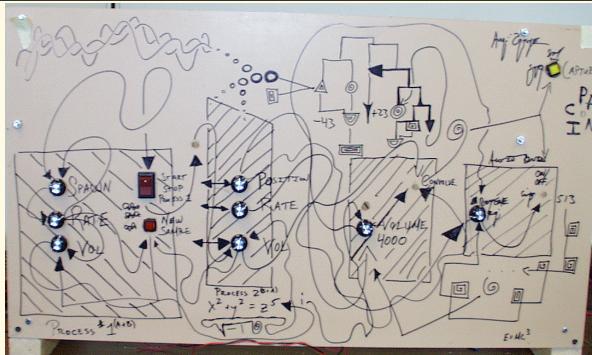
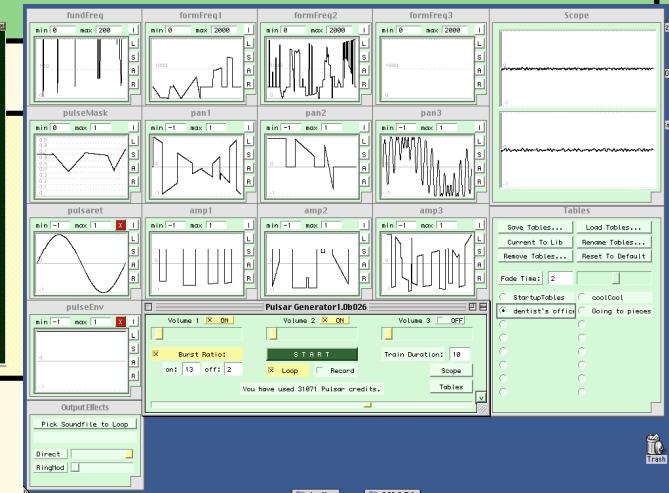
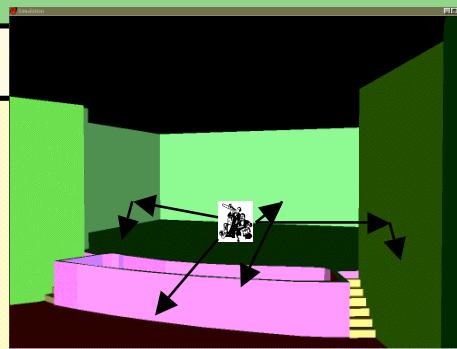


CRAM Configuration for CSL



Related Projects at CREATE

- Auralizer & VRML
- Pulsar Generator
- Creatovox
- MusicVisualization
- FMAK DB
- TimeMachine
- InteractEMGroup
- Creatophone
- Time-DDecomp
- SC_3 Work



CREATE