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

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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
How? DSCP!

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**

**Sensors**
- MIDI
- Matrix
- Graphonic
- OT_Kbd
- Creatovox
- VR Trackers
- Mot. Capture
- AdC_Panner
  (LAN is switched 1000BaseT)

**Gesture Mapping**
- Wintel PCs
- Apple G5s

**Synthesis**
- Apple Xserves
- Apple G5s/G4s
- Sun Ultras
- SGI Octanes

**Spatial output**
- Apple G5
- Echo Layla

**Interfaces**
- Occam/Macco
- OscAR
In Pictures

Compositional Model

Spatialization Model

Gesture Sensors

Output Drivers

CSL Server Farm

Surround Output
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)
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);
Multi-host CSL Graphs

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

RemoteIO root, server

RemoteFrameStream node, client

HostA

CSL RFS protocol (TCP, UDP, ATM)

HostB

IO

OSC
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, caching/differencing/throttling, OSC out

• GestureSensors: receive OSC or MIDI
  
  ```c
  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?

• **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 **persistency**

[440 Hz, (1/4 beat), 44 dB]
evtList mapPltches: gamut.
evtList playOn: Voice default.
Siren Components (1992)
Siren 2003 (VisualWorks)
Siren Tools 1984-2004
The CREATE Signal Library (CSL, “sizzle”) (“chill?”)

- 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

Sine wave with envelope

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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);
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)
Multi-host CSL Graphs

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

RemoteIO root, server

CSL RFS protocol (TCP, UDP, ATM)

RemoteFrameStream node, client
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
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  ```
  void * mData; // data array (typically a float *)
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• Subclasses
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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,4.0,0.3,220.0,0.357.4,3.0; 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 transmedia 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 Mgmnt. 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

Demo
CRAM Configuration for CSL
Related Projects at CREATE

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