Sonification in ChucK, MiniAudicle and STK

Perry R. Cook, ICAD Workshop, Atlanta, June 2012

ChucK Language Intro, Basics:

Hello Sine!

```
SinOsc s => dac;       // connect a sine oscillator to audio out
1.0 :: second => now; // advance time by 1 second (thus, sound)
```

The ChucK Operator => connection (patching), assignment, argument passing, time

```
SinOsc sl => dac.left;  // connect sine osc to dac left channel
SinOsc sr => dac.right; // connect another sine to dac right channel
200.0 => sl.freq;      // assign 200.0 to the frequency of left sine
sr.freq(202.0);        // assign 202.0 to frequency of right sine
5.0 :: second => now;  // hang out for 5 seconds
204.0 => sr.freq;      // set right sine freq to 204 Hz.
4.0 :: second => now;  // hang out another 4 seconds
```

The Mini Audicle: Smart Editor, Virtual Machine Monitor, Console, Shred Handling, …

```
SinOsc s => JCRev r => dac;             // sine thru reverb to dac
while (true)    {                       // infinite loop
    Std.rand2f(200.0,1000.0) => s.freq; // 200-1000 Hz. random freq.
    0.2 :: second => now;               // hang out for 1/5 second
}
```

Modifications:

```
0.01 => r.mix;          // change dry/reverb mixture
                        //     even on the fly!!!
```

Or…

```
1.0 :: samp => now;     // update every sample
```

On-the-fly Coding/Editing/Debugging: Virtual Machine, Shreds, Concurrency

Precise Control of Time: samp, second, ms, day, week, fractions/multiples of any of these

```
Impulse imp => dac;          // impulse generator (gateway) to dac
while (1)    {               // infinite loop
      Std.rand2f(0.01, 0.1) :: second => now;  // random waiting time
      1.0 => imp.next;       // randomly timed pulses, Geiger to noise
}
```

Data Types: int, float, time, dur, void, complex, polar

show examples of math on time, strong typing, casting, etc.

Objects: An Object is an encapsulated collection of data and behavior (more on this later)

Class, inheritance, message passing (ChucK), polymorphism (behavior)

Object: base (mother) class of all other classes

Array: N-dimensional ordered set of data (of same type)

UGen: Unit Generator base class (SinOsc, JCRev, etc. Inherit from this)

Others Event, string

ChucK Language Intro (cont), a Little More Advanced:

Arrays, Looping

```
SinOsc s => dac;                                     // our sine buddy
[60, 62, 64, 65, 67, 69, 71, 72] @=> int notes[];   // array of ints
for (0 => int i; i < notes.cap(); 1 +=> i) {       // basic for loop
      Std.mtof(notes[i]) => s.freq;      // set freq by midi notes
      0.5 :: second => now;
}
```

Modify above example, change notes, add duration array, other

Concurrency, Synchronization

```
Impulse imp => TwoPole f => JCRev r => dac; // tuned “pops”
0.04 => r.mix;                            // dry/reverb mix
0.99 => f.radius;                         // set up filter to ring
0.2 :: second => dur T;                   // set up basic note period
while (1)  {
      Std.rand2f(500.0,2000.0) => f.freq; // random filter freq
      1.0 => imp.next;                    // make an impulse
      T => now;
}
```

Fire up a few of these, note that they all work, but synchronized?
Add this line to it, before the while loop:

```
T - (now % T) => now;  // Huh?  Compute and delay time until next T
```

Play around with changing T, changing frequency limits, etc. Music!!

Functions

Built in: Std.fabs(x), Math.sqrt(x), UG.gain(x), Machine.add(process), me.args(), …
User Defined:

```
fun int couldbe(float prob)  { // return true/false based on prob 0-1
      if (Std.rand2f(0.0,1.0) < prob) return 1;
      else return 0;
}

fun void sweepUp(float initFreq) {         // function definition
    SinOsc s => dac;                       // alloc UG (not a good idea)
    while (s.freq() < 10.0*initFreq) {   // sweep to 10x initial
        s.freq() * 1.01 => s.freq;         // expon. ramp frequency
        0.01 :: second => now;
    }
    s =< dac;                             // unchuck (for GC (later))
}
```

Shreds, Spork(ing):   non-preemptive threads

```
while (1)  {
    if (0.2 => couldbe) spork ~ sweepUp(100.0);      // 1/5 chance low
    else spork ~ sweepUp(Std.rand2f(500.0,1000.0)); // otherwise, hi
    Std.rand2f(0.3, 2.0) :: second => now;
}
```

Chuck Language Math Library:

Math.sin(x), cos(x), tan(x), asin(x), acos(x), atan(x), atan2(x,y)
sinh(x), cosh(x), tanh(x), hypot(x,y)
pow(x,y), sqrt(x), exp(x), log(x), log2(x), log10(x)
floor(x), ceil(x), round(x), trunc(x), fmod(x,y), remainder(x,y)
min(x,y), max(x,y), nextpow2(x)
isinf(x), isnan(x)

```
Impulse imp => dac;  // provides a means of writing directly to dac
0.0 => float phase;  // make a phase variable for sine argument
while (1)  {
       Math.sin(phase) => imp.next;            // write out next sample
       0.1 +=> phase;                          // increment phase
       if (phase > (2*pi)) phase-(2*pi) => phase;  // modulo two pi
       1.0 :: samp => now;                    // write out each sample
}
```

ChucK Language Standard Library (Std)

int **abs** (int **value**); *returns absolute value of integer*

float **fabs** (float **value**); *returns absolute value of floating point number*

int **rand** ( ); *generates random integer*

int **rand2** (int **min**, int **max**); *generates random integer in range [min, max]*

float **randf** ( ); *generates random floating point number in the range [-1, 1]*

float **rand2f** (float **min**, float **max**); *random float in the range [min, max]*

float **sgn** (float **value**); *compute sign of input as -1.0 (neg), 0, or 1.0 (pos)*

int **atoi** (string **value**); *converts ascii (string) to integer (int)*

string **itoa** (int **value**); *integer to ascii (string)*

float **atof** (string **value**); *convert ascii (string) to floating point value (float)*

float **ftoa** (string **value**); *float to ascii (string)*

float **mtof** (float **value**); *converts a MIDI note number to frequency (Hz)*
note the input value is of type 'float' (supports fractional note number)

float **ftom** (float **value**); *convert frequency (Hz) to MIDI note number space*

float **powtodb** (float **value**); *convert signal power ratio to decibels (dB)*

float **rmstodb** (float **value**); *convert linear amplitude to decibels (dB)*

float **dbtopow** (float **value**); *convert decibels (dB) to signal power ratio*

float **dbtorms** (float **value**); *converts decibles (dB) to linear amplitude*

plus maybe some other undocumented ones ☺

Some more Std. functions (System Power Tools)

int **system** (string **cmd**); *pass a command to be executed in the shell*

string **getenv** (string **key**); *returns the value of an environment variable, such as of "PATH"*

int **setenv** (string **key**, string **value**); *sets environment variable named 'key' to 'value'*

Machine Commands: **Machine.add(“MyCode.ck”) => int myShred; Machine.remove(myShred);**

int **add** (string **path**); *compile and spork a new shred from file at 'path' into the VM now, returns the shred ID*

int **spork** (string **path**); *same as add*

int **remove** (int **id**); *remove shred from VM by shred ID (returned by add/spork)*

int **replace** (int **id**, string **path**); *replace shred with new shred from file*

int **status** ( ); *display current status of VM*

void **crash** ( ); *literally causes the VM to crash. the very last resort; use with care. Thanks.*

me Object:

me.id(); me.yield(); me.exit(); me.running(), me.clone(), me.done(), me.nargs(), me.arg();

ChucK Language Unit Generators:

global special unit generators:
adc dac blackhole

standard ChucK unit generators:
SinOsc PulseOsc SqrOsc TriOsc SawOsc Phasor Noise Impulse Step Gain
SndBuf HalfRect FullRect ZeroX Mix2 Pan2 GenX CurveTable WarpTable LiSa

filters:
Filter OneZero TwoZero OnePole TwoPole PoleZero BiQuad LPF HPF BPF BRF ResonZ Dyno

STK unit generators in ChucK:
Envelope ADSR Delay DelayA DelayL Echo JCRev NRev PRCRev Chorus Modulate PitShift
SubNoise Blit BlitSaw BlitSquare WvIn WaveLoop WvOut

STK instruments unit generators
StkInstrument BandedWG BlowBotl BlowHole Bowed Brass Clarinet Flute Mandolin
ModalBar Moog Saxofony Shakers Sitar StifKarp VoicForm
FM BeeThree FMVoices HevyMetl PercFlut Rhodey TubeBell Wurley

All UGs obey gain(float), op(int), last(), channels(), chan(int), most have other properties

```
// Simple FM Example
SinOsc modulator => ADSR menv => SinOsc carrier => ADSR cenv => dac;
2 => carrier.sync;        // setup carrier input for FM
cenv.set(0.01 :: second, 0.1 :: second, 0.5, 1.0 :: second);
menv.set(0.2 :: second, 0.2 :: second, 0.3, 1.0 :: second);
1000.0 => carrier.freq;  // roughly the spectral center
100.0 => modulator.freq; // roughly the "pitch" (or inharmonic)
500.0 => modulator.gain; // make this enough to do good modulation
1 => cenv.keyOn => menv.keyOn;     // spark this baby up!
0.2 :: second => now;              // let it get rolling
1 => cenv.keyOff => menv.keyOff;   // shut ‘er down
2.0 :: second => now;              // let it finish up
```

Objects/Classes

```
/* Define a new Class in one file */

    public class FluteSweep  {
        Flute f;                              // Flute physical model
        int sweeping;

        public void connect(UGen ugen) { f => ugen; } // connection

        public void blow(float freq) {        // blow with float argument
            freq => f.freq;
            1 => f.noteOn => f.pressure;
            spork ~ sweepUp(); }

        public void blow(int note) {        // overload/polymorph function
            blow(Std.mtof(note)); }         // use existing mechanics

        public void shaddap()  {
            1 => f.noteOff;                 // noteOff
            0 => sweeping; }

        private void sweepUp()  {
            0.5 :: second => now;            // let the note establish
            f.freq() => float temp;          // low starting freq
            temp * 8.0 => float temp2;       // ending frequency
            1.0 => float bl;                 // beginning blowing pressure
            1 => sweeping;                   // state variable for blowing
            while ((temp < temp2) & sweeping)  {
                temp * 1.02 => temp => f.freq;    // sweep freq up
                0.93 * bl => bl => f.noteOn;  // ramp down blowing
                0.01 :: second => now;
            }
        }
    }
```

```
/* Then you can use that class in any other subsequent file */

    FluteSweep f;                      // make a new FluteSweep Object
    f.connect(dac);                    // hook it up to audio out

    [60, 62, 63, 65, 66, 67, 71, 72] @=> int notes[]; // CMaj scale

    for (0 => int i; i < notes.cap(); i++)  {  // shorthand increment
        f.blow(notes[i]);
        0.9 :: second => now;
        f.shaddap();
        0.1 :: second => now;
    }
```

Hook it to MIDI, Make an array of them, whatever you like!!

Events

Some asynchronous object => now; (MIDI, OSC, MAUI Button, Slider, etc.)
// we'll see that shortly

```
// signalEvent.ck : signaling events

Event e;                     // declare an event

fun int hi( Event e )     {  // declare function that uses event
    <<< "OK, now what?" >>>;
    e => now;    // wait on event e
    <<<"success">>>;         // only happens AFTER e is signaled
}

spork ~ hi( e );             // spork shred with e

1.0 :: second => now;        // advance time

e.signal();                  // signal e (could also e.broadcast()

1.0 :: samp => now;          // hang around just one samp longer
```

See also the Conducting with Events programs

MIDI

```
0 => int device;  // device # to open (see: chuck --probe)
if( me.args() ) me.arg(0) => Std.atoi => device;  // get command line

MidiIn mdin;                            // the midi event
MidiMsg msg;                            // message for retrieving data

if( !mdin.open( device ) ) me.exit();   // open the device
<<< "MIDI device:", mdin.num(), "->", mdin.name() >>>;  // print device

SinOsc s => dac;                        // our "synth"
0.0 => s.gain;

while( true )   {    // infinite time-loop
      mdin => now;                            // wait on event 'mdin'
      while( mdin.recv(msg) )  {                    // get message(s)
           <<< msg.data1, msg.data2, msg.data3 >>>; // print message
           if (msg.data1 == 144) {                  // if NoteOn msg
                 Std.mtof(msg.data2) => s.freq;     // set freq
                 msg.data3 / 127.0 => s.gain;       // Note On
           }
           else 0.0 => s.gain;          // Note Off (stupid version)
      }
}
```

OSC (Open Sound Control)

```
// Simple OSC Sender Example
"localhost" => string hostname;         // who we're gonna talk to
6449 => int port;                       // port we're gonna talk on
OscSend xmit;                           // OSC Send Object
xmit.setHost( hostname, port );         // open and hook it up

while( true )    {
    xmit.startMsg( "/foo/notes", "i f" ); // start msg, int, float
    Std.rand2( 30, 80 ) => xmit.addInt;   // fill in the int
    Std.rand2f( .1, .5 ) => xmit.addFloat; // fill in float
                                         // message is sent now
    0.2::second => now;
}
```

```
// Simple OSC Receiver Example

Rhodey ins => JCRev rev => dac;               // “synth”
.1 => rev.mix;

OscRecv recv;                                 // make a receiver
6449 => recv.port;                            // on port number
recv.listen();                                // start the receiver up
recv.event( "/foo/notes, i f" ) @=> OscEvent @ oe; // format message

int i;
float f;
while( true )   {
    oe => now;                    // wait for message to come in
    while( oe.nextMsg() )  {      // peel off the arguments
        oe.getInt() => i => Std.mtof => ins.freq; // and use
        oe.getFloat() => f => ins.gain;           // them for . . .
        f => ins.noteOn;                          // . . . music!!
        <<< "got (via OSC):", i, f >>>;
    }
}
```

See iPhone Singer (TouchOSC App => ChucK Formant Voice) (note WiiOSC, other)

See Draw Homer (Processing Drawing => ChucK “Dope!” manipulation)

See Video Action (Processing Video => ChucK Synthesis) (note FaceOSC too)

Try to do a net-conducted ICADDTOrk “piece” (before or after break)

BREAK!!!!!!!

HID, SMELT

Keyboard, Mouse, Trackpad, Joystick (various), Accelerometers, mic (adc)

```
// Use laptop shaking to control model of coin in mug
Shakers peso => JCRev rev => dac.right;   // coin in coffee mug
0.03 => rev.mix;
19 => peso.preset; 10 => peso.objects;    // setup parameters
1.0 => peso.decay; 1 => peso.noteOn;    // and git this party started

Hid hi;                                   // make a Hid object
HidMsg msg;                               // and holder for messages
if( !hi.openTiltSensor() )  {             // open tilt sensor
    <<< "tilt sensor unavailable", "" >>>;
    me.exit();
}
<<< "tilt sensor ready", "" >>>;         // if success opening hid

float lacc[3];                      // to hold our last accel values

while( true )   {
    hi.read( 9, 0, msg );            // read accel (device 9) number 0
    //     <<< msg.x, msg.y, msg.z >>>; // (optional) print results
    (msg.x - lacc[0])*(msg.x - lacc[0]) => float shaking; // get total
    (msg.y - lacc[1])*(msg.y - lacc[1]) +=> shaking; // 3D squared
    (msg.z - lacc[2])*(msg.z - lacc[2]) +=> shaking; // velocity
    shaking / 4000.0 => peso.energy;    // and use that to shake model
    msg.x => lacc[0]; msg.y => lacc[1]; msg.z => lacc[2];// store last
    30 :: ms => now;                    // hang out until next read
}
```

Another example using "wind"

```
// Use wind on microphone to excite virtual bamboo wind chimes
Shakers bamboo => JCRev rev => dac.right;       // bamboo wind chimes
5 => bamboo.preset; 1.0 => bamboo.decay; 4 => bamboo.objects;
adc => LPF lp => LPF lp2 => LPF lp3;   // chain of low pass filters
50.0 => lp.freq => lp2.freq => lp3.freq; // set them up to pass
4.0 => lp.Q => lp2.Q => lp3.Q;           // only low frequencies
lp3 => OnePole envFollow => blackhole; // envelope follower
0.999 => envFollow.pole;  200.0 => envFollow.gain; // wind detector
3 => envFollow.op;  lp3 => envFollow;               // square input
0.03 => rev.mix;

1 => bamboo.noteOn;                         // git this party started

while (1)  {
    0.05 :: second => now;                  // update wind signal to
    envFollow.last() => bamboo.energy;      // drive particle model
}
```

Also Demo Some Tether Controller Examples

UANAs, SMIRK

UpChucK!!! (vector buffer operations)

```
//  FFT-based pitch shifting down by an octave.
adc => FFT fft =^ IFFT ifft => dac;     // DSP Chain

1024 => fft.size => ifft.size;          // Size
Windowing.hamming(512) => fft.window;   // Window for smoothing
UAnaBlob blob;                          // Blob to hold data

while (1)   {
    256 :: samp => now;                 // Advance time by hopsize
    fft.upchuck() @=> blob;             // Get data
/**/ for (0 => int i; i < fft.size()/4; 1 +=> i)    {
/**/    blob.cvals()[i*2] => blob.cvals()[i]; // Copy spectrum
/**/ }                                        // down by octave
    ifft.upchuck();                     // Inverse FFT and output
}
```

Getting Features from Spectral Data

```
//  Use FFT to track main peak in spectrum with a sine wave
adc => FFT fft => blackhole;      // draw samples through FFT
SinOsc s => dac;                  // Our "synthesizer"

2048 => fft.size;
Windowing.hamming(1024) => fft.window;
UAnaBlob blob;

while (1)   {
    512 :: samp => now;                     // Hop along by size/4
    fft.upchuck() @=> blob;                 // Compute and
    blob.fvals() @=> float mag_spec[];      //      store spectrum
    0.0 => float peak;
    0.0 => float power;
    0 => int peakloc;
    for (0 => int i; i < fft.size()/2; 1 +=> i)     {
        mag_spec[i]*mag_spec[i] +=> power;       // Accumulate power
        if (mag_spec[i] > peak)    {             // Find peak
            mag_spec[i] => peak;
            i => peakloc;
        }
    }
    44100.0 * peakloc / fft.size() => s.freq;       // Set freq
    Math.sqrt(power) => s.gain;                     // Set gain
    //    <<< s.freq() >>>;
}
```

Demo more FFT Examples, Features, 1NN Classifiers

Point to WEKINATOR

Multi-channel support

```
// Multi-channel output example
dac.channels() => int numChans;  // number of available channels

SinOsc s[dac.channels()];    // suitable sized array of sin oscs
200.0 => float freq;         // base frequency variable

for (0 => int i; i < numChans; i++)  { // iterate over all channels
    freq => s[i].freq;                  // set sin osc frequency
    s[i] => dac.chan(i);                // hook up to dac channel
    1.059 * freq => freq;               // frequency up by half step
    2.0 :: second => now;               // hang out a bit
}
2.0 :: second => now;                   // hang out a bit
```

File I/O

SndBuf, WvIn, WaveLoop, WvOut, FileIn, FileOut (NetIn, NetOut) (SerIn, SerOut soon)

```
SndBuf s => WvOut w => dac; // make a sndbuf and hook it to audio out
"special:dope" => s.read; // this could be any valid .wav, other
"test.wav" => w.wavFilename;  // this opens a sound file for writing
FileIO log;                  // make a data file object
log.open( "LOG.txt", FileIO.WRITE ); // and open it for writing

s.length() => now;                // let it play once

-1.0 => s.rate;                   // set it to play backward
(s.length()/samp) $ int => s.pos; // set play position to end
s.length() => now;                // let it play backward

1 => s.loop;                      // set it to loop
0 => int counter;

now + 10.0 :: second => time then;            // let this run for
while (now < then)  {                         // exactly 10 seconds
    Std.rand2f(0.0,s.length()/samp) $ int => s.pos; // random position
    Std.rand2f(-2.0,2.0) => s.rate;               // random rate
    Std.rand2f(0.1,1.0) :: second => now;         // for random time
    1 +=> counter;
}
w.closeFile();                                // clean up sound file

log.write("We visited some part of Homer a total of "); // write some
log.write(counter);                           // meaningful info into
log.write(" times. \n");                      // our log file
log.close();                                  // and close it
```

Show this with some other .wav .aif files

Some More Sonification Examples:

Desktop/Browser (cursor with regions)

Google Stock Prices Min, Max, Volume, Closing

Light/Motion/Red/Blue in Lobby FM Bells?

Joint-angle (finger) musification

Extending ChucK: ChuGens, ChuGIns, and ChubGraphs

These are all Class definitions, but work as, or inherit from, UGen

Chugen \choo-jen\ (define your own UGs from within ChucK) example:

```
class MyCosine extends Chugen  {
    0 => int p;
    440 => float f;
    second/samp => float SRATE;

    fun float tick(float in)  {
        return Math.cos(p++ * 2 * pi * f / SRATE);
    }
}
```

Chubgraph (define your UG, but must use only existing UGs) example:

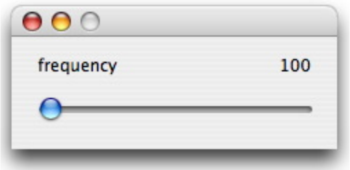
```
class Feedback extends Chubgraph  {
    inlet => Gain dry => outlet;
    dry => Delay delay => outlet;
    delay => Gain feedback => delay;
    0.8 => feedback.gain;
    1 :: second => delay.delay;
}

SinOsc s => Feedback f => dac;

1.0 :: second => now;
300.0 => s.freq; 2.0 :: second => now;
1000.0 => s.freq; 1.0 :: second => now;
100.0 => s.freq; 3.0 :: second => now;
```

ChuGin \chug-in\ (define your own UGs in C/C++), outside our scope today

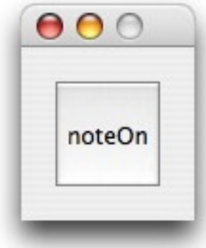
FaucK (Faust diagrams can generate ChucK ChuGins), outside our scope

Enough Already, Time to Hack ChucK!!!!!!! (in a second…)

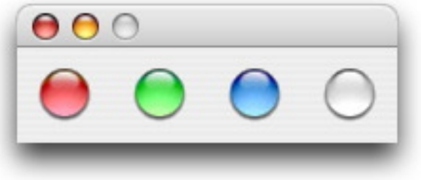
MAUI (MiniAudicle User Interface)
Mac Only (for now)



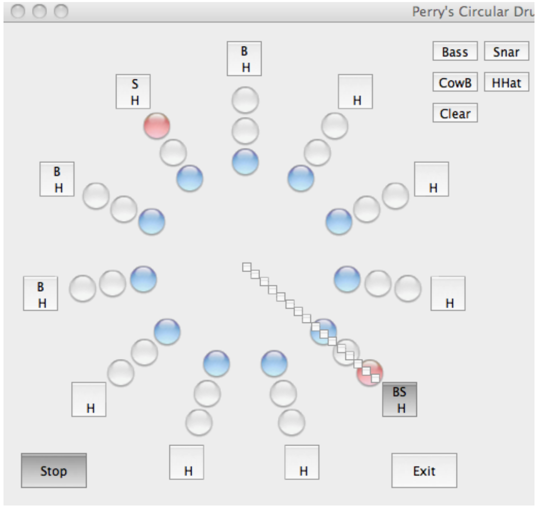
Sliders (Vertical and Horizontal)

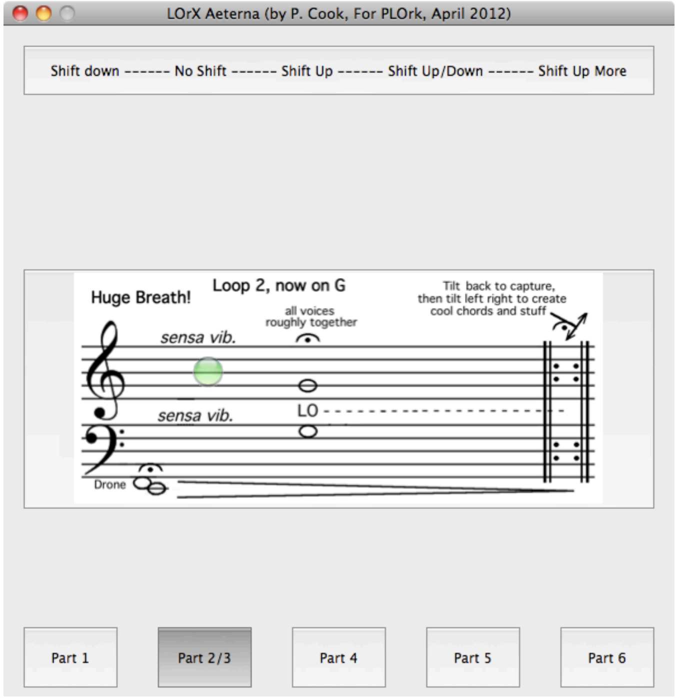


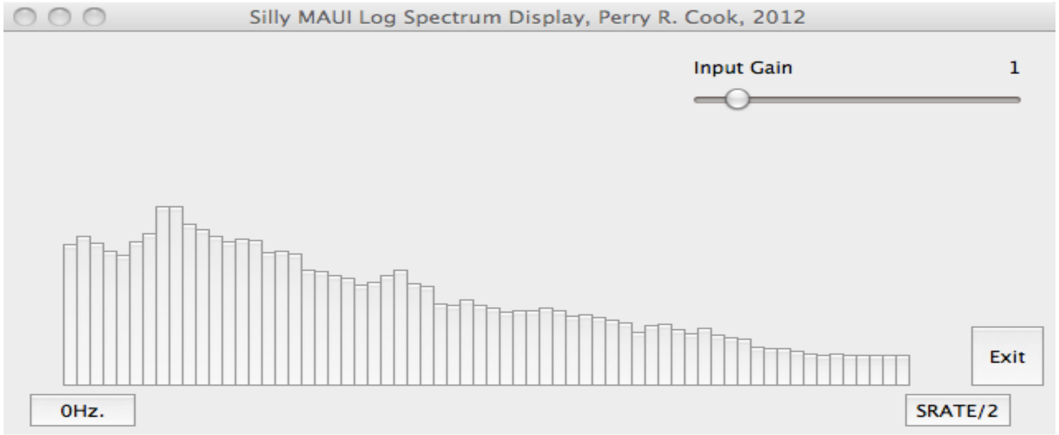
Buttons (with images)



LEDs




LOrX Aeterna (by P. Cook, For PLOrk, April 2012)
Shift down ------ No Shift ------ Shift Up ------ Shift Up/Down ------ Shift Up More
Huge Breath!
Loop 2, now on G
all voices roughly together
Tilt back to capture, then tilt left right to create cool chords and stuff
sensa vib.
sensa vib.
LO
Drone
Part 1
Part 2/3
Part 4
Part 5
Part 6



Synthesis ToolKit in C++

STK is a set of classes in C++ which allow rapid experimentation with sound synthesis and processing. Available for free:

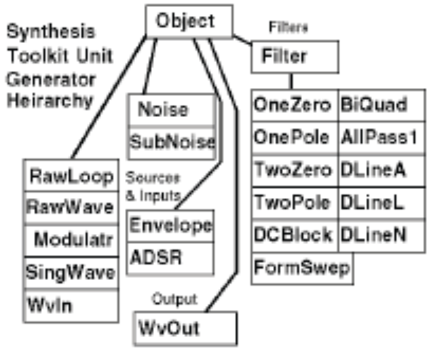
http://ccrma.stanford.edu/software/stk/

Ported and used a lot (Faust, mobile, …)

"Unit Generators" the classical computer music/sound building blocks:

Oscillators, Filters, Delay Lines, etc.

STK Unit Generators



Sources

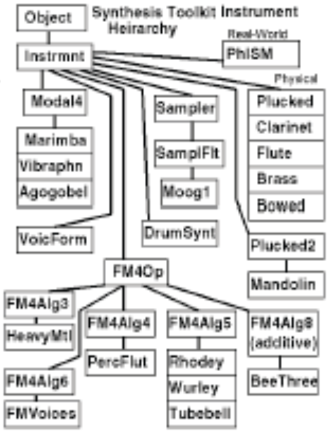
Sinks

Filters

STK Synthesis

PhISM
Modal
Samples
FM
Physical:

Plucked
Winds
Bowed



SKINI:
Synthesis toolKit Network Interface

Double Precision floats for:

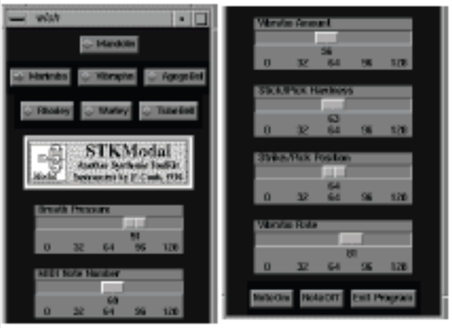
- Note Numbers (micro tuning or fine pitch control)
- Control Values (more precision)
- Delta times

Text Based (easy creation, editing, debugging)

Sockets (Pipes)

- Connection on local machine is same as on remote
- SKINI sources:
  - GUIs, MD2SKINI, Scorefiles, Any formatted text generator
- SKINI11.cpp parses SKINI messages

STK GUIs in TCL / TK



Common simple controls for all algorithms

References and Resources

Book on interactive sound synthesis

ChucK Book Coming (Soon-ish)

Book on all topics Sonification

ChucK is:

- Ge Wang
- Perry Cook
- Phil Davidson
- Spencer Salazar
- Many others

SMELT is: => Rebecca Fiebrink => Ge Wang

SMIRK is: => Rebecca Fiebrink => Ge Wang

Wekinator is: => Rebecca Fiebrink => Dan Trueman => Perry Cook

chuck.cs.princeton.edu
smelt.cs.princeton.edu
smirk.cs.princeton.edu

(join the forums!)

ccrma.stanford.edu/software/stk/
wekinator.cs.princeton.edu