Implementing a Polyphonic MIDI Software Synthesizer using Coroutines, Realtime Garbage Collection, Closures, Auto-allocated Variables, Dynamic Scoping, and Continuation Passing Style Programming

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Introduction

- Audio programming techniques
  - CS, not DSP
  - Low-latency (hard realtime)
  - Sample-by-sample
- Demonstrated by implementing MIDI software synthesizers
- Snd-RT
  - CLM
  - Stalin Scheme Compiler

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- Garbage collection
- Closures (and functional programming!)
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Why demonstrating a MIDI software synthesizer?

1. Both *audio rate* and *control rate*.
2. Variable polyphony.
3. Data allocation.
4. Bus routing.

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Implementing what is probably the simplest type of MIDI Soft Synth.

Basic MIDI Soft Synth

```
(<rt-stalin>
  (range note-num 0 128

    (define phase  0.0)
    (define volume 0.0)

    (sound
      (out (* volume (sin phase)))
      (inc! phase (midi->radians note-num)))

    (spawn
      (while #t
        (wait-midi :command note-on  :note note-num
          (set! volume (midi-vol)))
        (wait-midi :command note-off :note note-num
          (set! volume 0.0))))))
```

Realtime Memory Allocation and Garbage Collection

- Rollendurchmesserzeitsammler

Example

```
(define-stalin (softsynth)
  (while #t
    (wait-midi :command note-on
      (define phase 0.0)
      (define tone (sound
                    (out (* (midi-vol) (sin phase)))
                    (inc! phase (midi->radians (note-num)))))
      (spawn
        (wait-midi :command note-off :note (midi-note)
          (stop tone))))))

(<rt-stalin>
  (softsynth))
```

ADSR

Need to remove clicks when starting and stopping tones.

Example

```
(define-stalin (softsynth)
  (while #t
    (wait-midi :command note-on
      (spawn
        (define volume (midi-vol))
        (define phase 0.0)
        (define adsr (make-adsr :a 20:-ms :d 20:-ms :s 0.2 :r
        (define tone (sound :while (-> adsr is-running)
                            (out (* volume
                                    (-> adsr next)
                                    (sin phase)))
                            (inc! phase (midi->radians (midi-note)
        (wait-midi :command note-off :note (midi-note)
          (-> adsr stop))))))
```

Reverb

1. Dynamic scoping
2. Auto-Allocated variables

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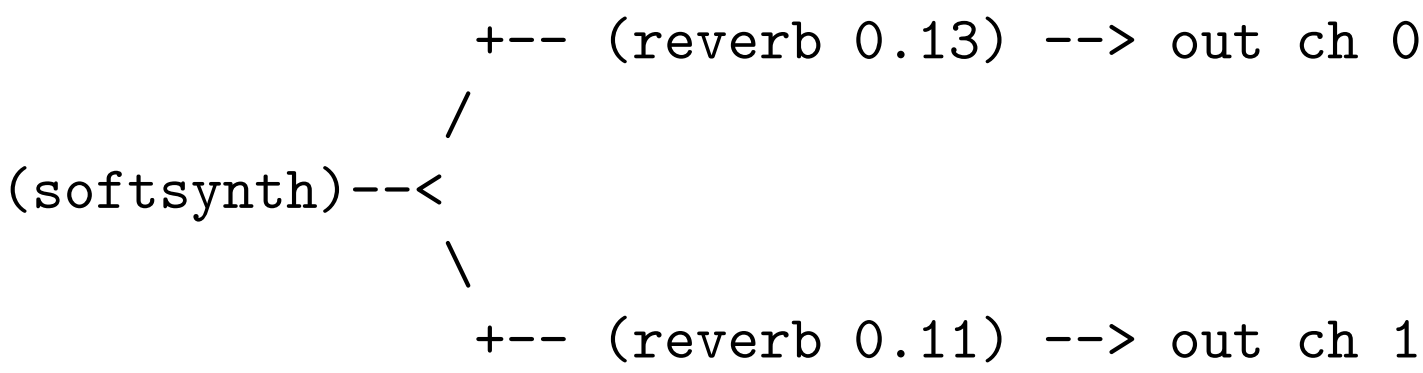
Example

```
(define-stalin (reverb input delay-time)
  (delay :size (* delay-time (mus-srate))
    (+ (comb :scaler 0.742 :size  9601 allpass-composed)
       (comb :scaler 0.733 :size 10007 allpass-composed)
       (comb :scaler 0.715 :size 10799 allpass-composed)
       (comb :scaler 0.697 :size 11597 allpass-composed)
       :where allpass-composed
         (send input :through
           (all-pass :feedback -0.7 :feedforward 0.7)
           (all-pass :feedback -0.7 :feedforward 0.7)
           (all-pass :feedback -0.7 :feedforward 0.7)
           (all-pass :feedback -0.7 :feedforward 0.7)))))
```

Simple Stereo Reverb



CPS Sound Generators. (Adding stereo reverb and autopanning)

1. Sound Generators, inspired by Faust / BDA
2. CPS is a programming technique
3. CPS means that no function will ever return
4. CPS provides a simple way to support more than one output

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Seq Operator

```
(Seq (between -1.0 1.0)
     (* 0.5))

->

(let ((generator0 (lambda (kont0)
                    (kont0 (between -1.0 1.0))))
      (generator1 (lambda (arg1 kont1)
                    (kont1 (* 0.5 arg1)))))
  (lambda (kont2)
    (generator0 (lambda (result0)
                  (generator1 result0 kont2)))))
```

Par Operator

```
(Par (* -1)
     (* 1))

->

(let ((generator0 (lambda (arg1 kont0)
                    (kont0 (* -1 arg1))))
      (generator1 (lambda (arg1 kont1)
                    (kont1 (* 1 arg1)))))
  (lambda (input2 input3 kont1)
    (generator0 input2
      (lambda (result0)
        (generator1 input3
          (lambda (result1)
            (kont1 result0 result1)))))))
```

Auto-Allocated variables in CPS Generators

```
(Seq (all-pass :feedback -0.7 :feedforward 0.7))

->

(let ((generator0 (let ((var0 (make-all-pass :feedback -0.7
                                             :feedforward 0.7)))
                    (lambda (kont input)
                      (kont (all-pass var0 input))))))
  (lambda (input kont)
    (generator0 input kont)))
```

Other CPS Generators

Split, Merge, Identity, Cut, Sum, Prod, Lambda, Buffer, Counter, Read-table, Sin, Incrementer, Osc and In.

Final version of the Midi Soft Synth

Final version of the MIDI Soft Synth.

Summary

- Garbage collection, Functional Programming, Coroutines, Faust

Questions.

Last slide