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Making music with occam-π

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Introduction

- Here's some work I did last year
- Originally a fringe presentation at CPA-2006
- An interesting application for process-oriented programming
- But first, some background…

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Electronic music

- . . . would be more appropriately called *computational* music
- Generating and processing sound using mathematics
- Not new at all – electronic synthesisers date back to the 1940s
  - Hammond Novachord, Ondioline, Theremin

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Analogue becomes digital

- Originally done with analogue electronics (much like analogue computers)
- Early work with digital computers in the 1950s-60s
  - UNIVAC I (1951), Bell Labs (1962)
- Digital electronics adopted as soon as they became available
- Commercial microprocessor-based systems in the 1970s
  - Synclavier, Fairlight CMI

The software age

- These days, we use microprocessors, DSPs, ...
- ... or software on general-purpose computers ("soft synths")
- Some modern keyboards are actually PCs running Windows/Linux!
- Interfaces and behaviours heavily influenced by the old analogue world

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How does it work?

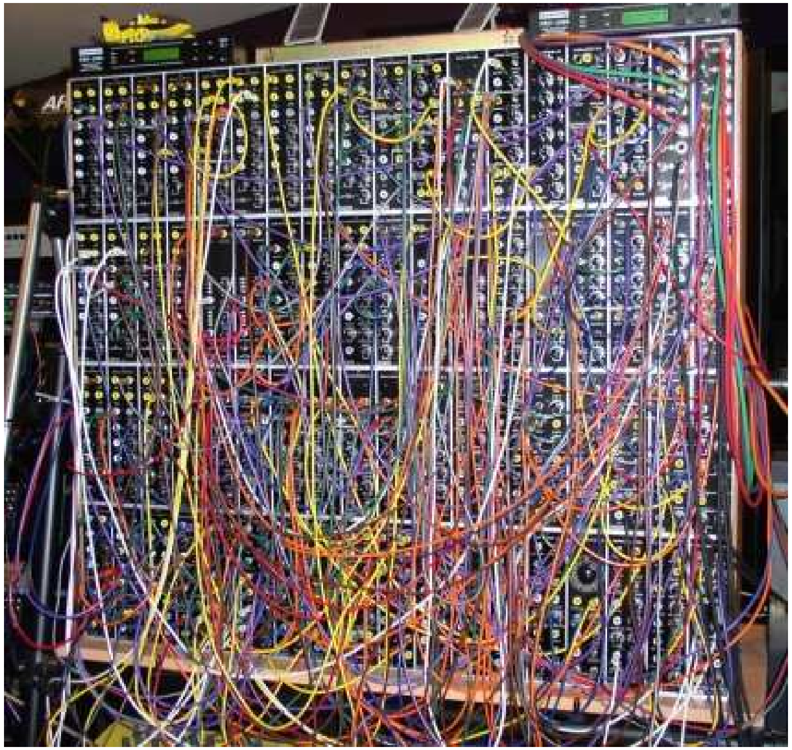
- Generate “pure” waveforms using oscillators
- . . . or process sound from an existing instrument (e.g. voice, guitar)
- Apply operators to modify and combine waveforms
  - Amplify, filter, mix, distort, modulate, delay . . .
- Demo later!

MIDI

- Connecting audio signals between devices is easy
- Sending control signals (“play note C-3 at volume 50”) is a bit more complex
- MIDI was introduced in 1981
- Reliable, low-speed serial links
- Standard messages for things like:
  - Note on/off
  - Controller change (e.g. pitch bend, pedals)
  - Generic purpose data dumps (“sysex”)

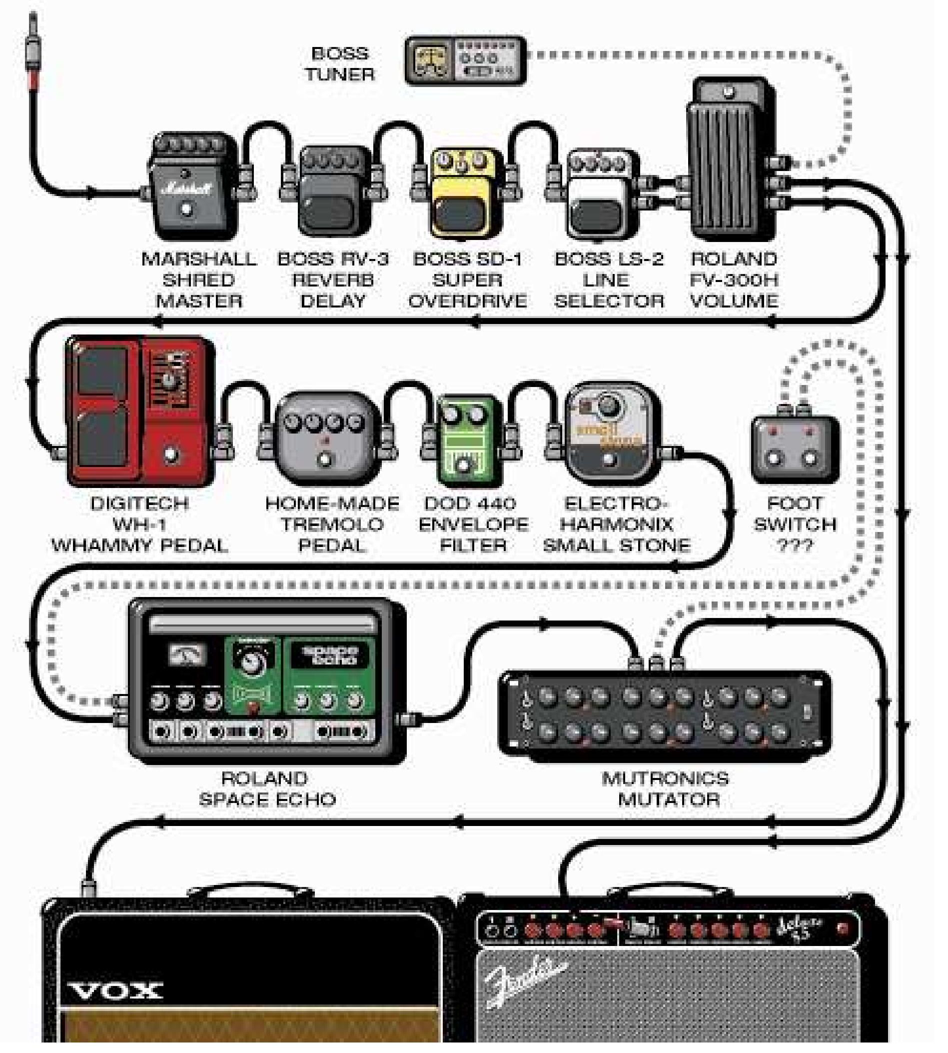
Little boxes

- We tend to think of this in terms of connecting up boxes
- Literally, with *modular* synthesisers (from uber.tv):



. . . all made out of ticky-tacky. . .

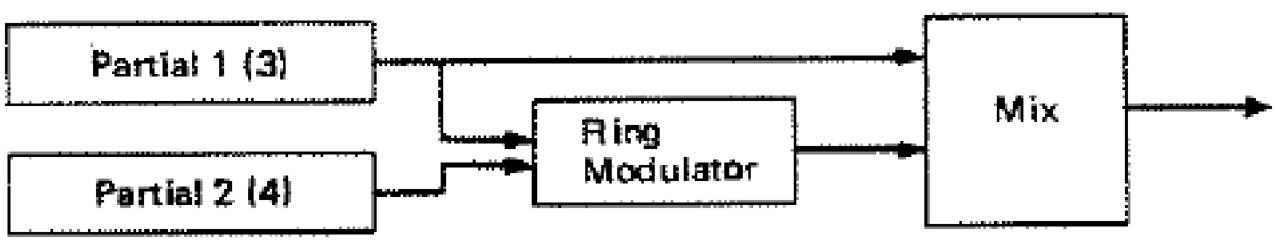
- . . . and guitar effects (from guitargeek.com):



. . . and they all look just the same

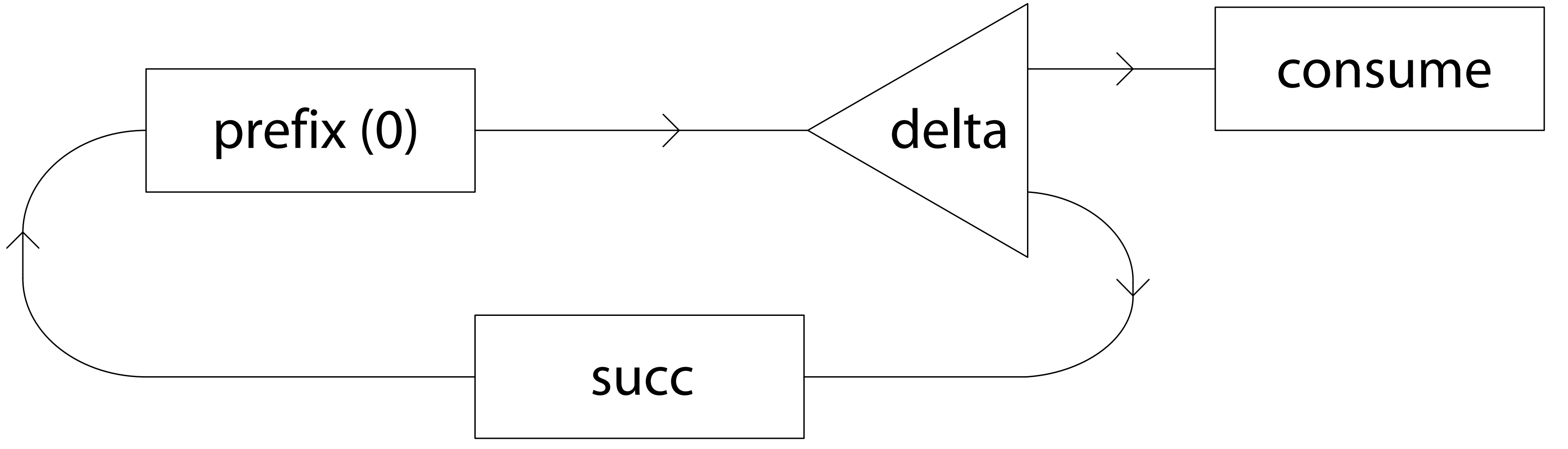
- . . . which means that software components are often described the same way (from the Roland D-110 manual):

Partial 1 (or 3) is mixed with the ring modulated sound of two Partials (including Partial 1 or 3).



- Lots of software uses this notation to let you build software synths – Pd, Max/MSP, . . .
- Does this look familiar?

Parallel worlds



- (from about 500 papers about occam-π– this one's Mario's)
- We use the same approach when designing process-oriented programs
- Boxes are processes; lines are channels

Why is this interesting?

- Like any research group, we're always looking for applications. . .
- Fine-grained, high-performance concurrency
- Many potential users who think about problems like we do
- . . . and are even using "our" notation
- Want to build reliable, scalable systems
- (Plus many of us are musicians already!)

OAK

- First shot at building a synthesiser in occam-π
- `DATA TYPE SIGNAL IS [BLOCK.SIZE]REAL32:`
- Many simple components – oscillators, operators, input/output
  - Most are direct equivalents of modular synth modules
  - Most operators are < 10 lines of code
- Can sequence music using occam-π code:
  `out ! note; C.3; SQ`
- Supports MIDI input from real devices

A simple component

- Amplifier – just multiply all incoming numbers by a constant:
- Just like the CO631 examples:

```
PROC amp (CHAN SIGNAL in?,
          VAL REAL32 factor,
          CHAN SIGNAL out!)
  WHILE TRUE
    SIGNAL s:
    SEQ
      in ? s
      out ! signal ([i = 0 FOR BLOCK.SIZE |
                     s[i] * factor])
:
```

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Problems with OAK

- Completely static – must recompile to change layout or parameters
  - Makes it awkward to develop new sounds
- Not very efficient
  - Data is often copied
  - All processes run on every cycle
- Proved that the concept was workable, though. . .

Meanwhile, in experimental music. . .

- People have been creating sounds and music by writing software since the 1960s
- Increasingly important in the last 20 years
- . . . but not normally done as part of a performance!
- Why not?

Live programming (2000 -)

- You don't have to play an instrument to appreciate the performance
- Helps involve the audience more in the performance
  - Often a problem with electronic music
- More opportunities for improvisation – sounds as well as melodies
- Control video/lighting too
- Raises some interesting problems

Languages for live programming

- Must be highly expressive – make changes rapidly
- Must be possible to make incremental changes
- Control over when changes take effect
- Robust against programmer error
- Reliable – avoid glitches in the output and timing problems
- Needs both language and development environment support
- Notion of concurrency
- Existing examples: ChucK, fluxus (Scheme), feedback (Perl), . . .

LP from a POP perspective

- Kernel for lightweight concurrency – check
- Writing occam on the fly is right out!
  - So use the graphical notation the users already understand
  - Graphical process network editor – we've done this before
- We know how to build robust POP systems
  - Design component interfaces to support live rewiring
  - Apply design rules on the fly to ensure safety

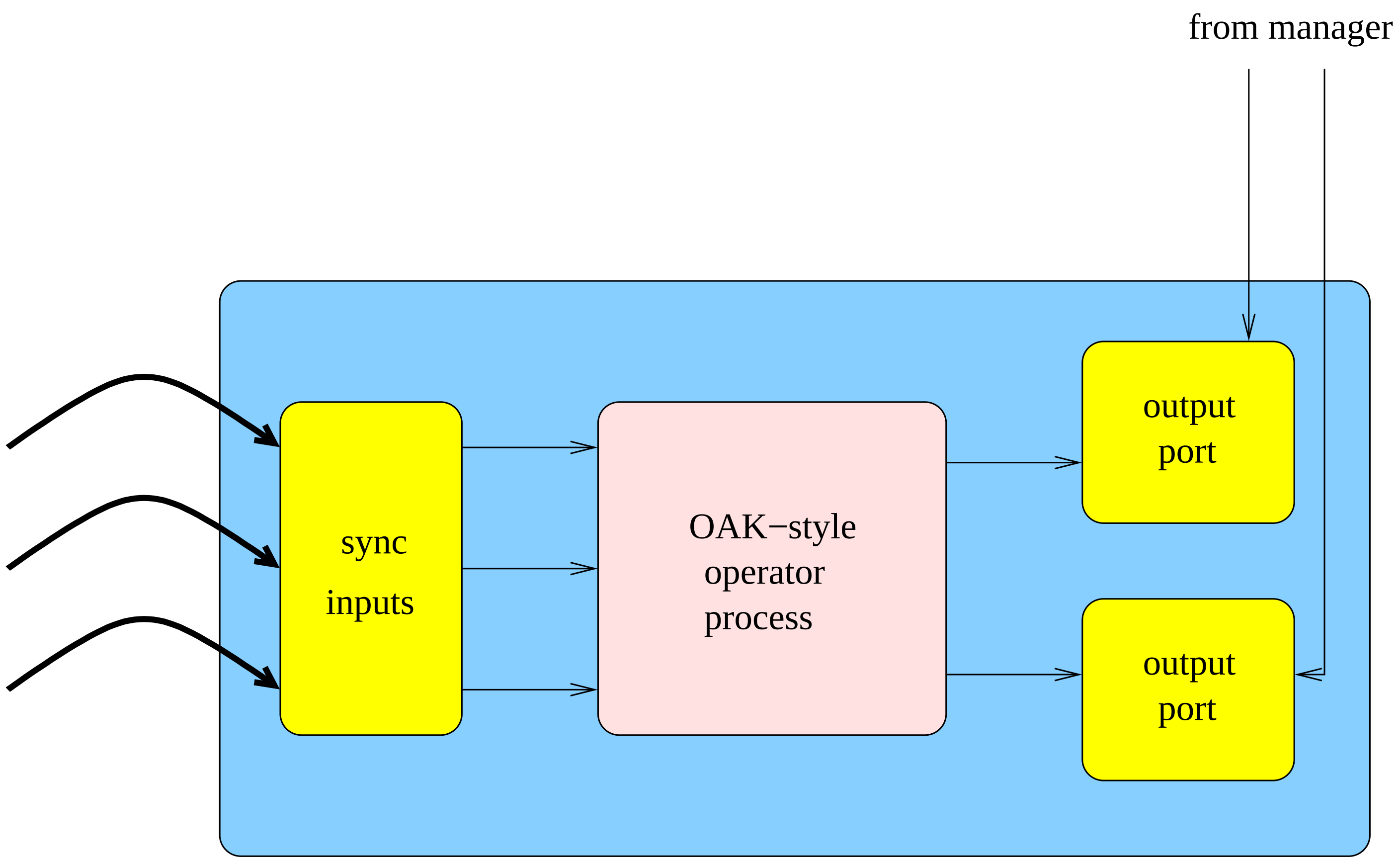
LOVE

- Time for a demo!
- Introducing the Live occam-π Visual Environment. . .
- Proof-of-concept software – sorry if it all goes horribly wrong

What is LOVE?

- The second generation, after OAK
- Components can be created at runtime
- Dynamic, repluggable connections
- GUI – events, visualisation, changing settings
- Data copying is minimised
- Processes can sleep

Components in LOVE



- Same process, with wrappers to provide ports

The code for that

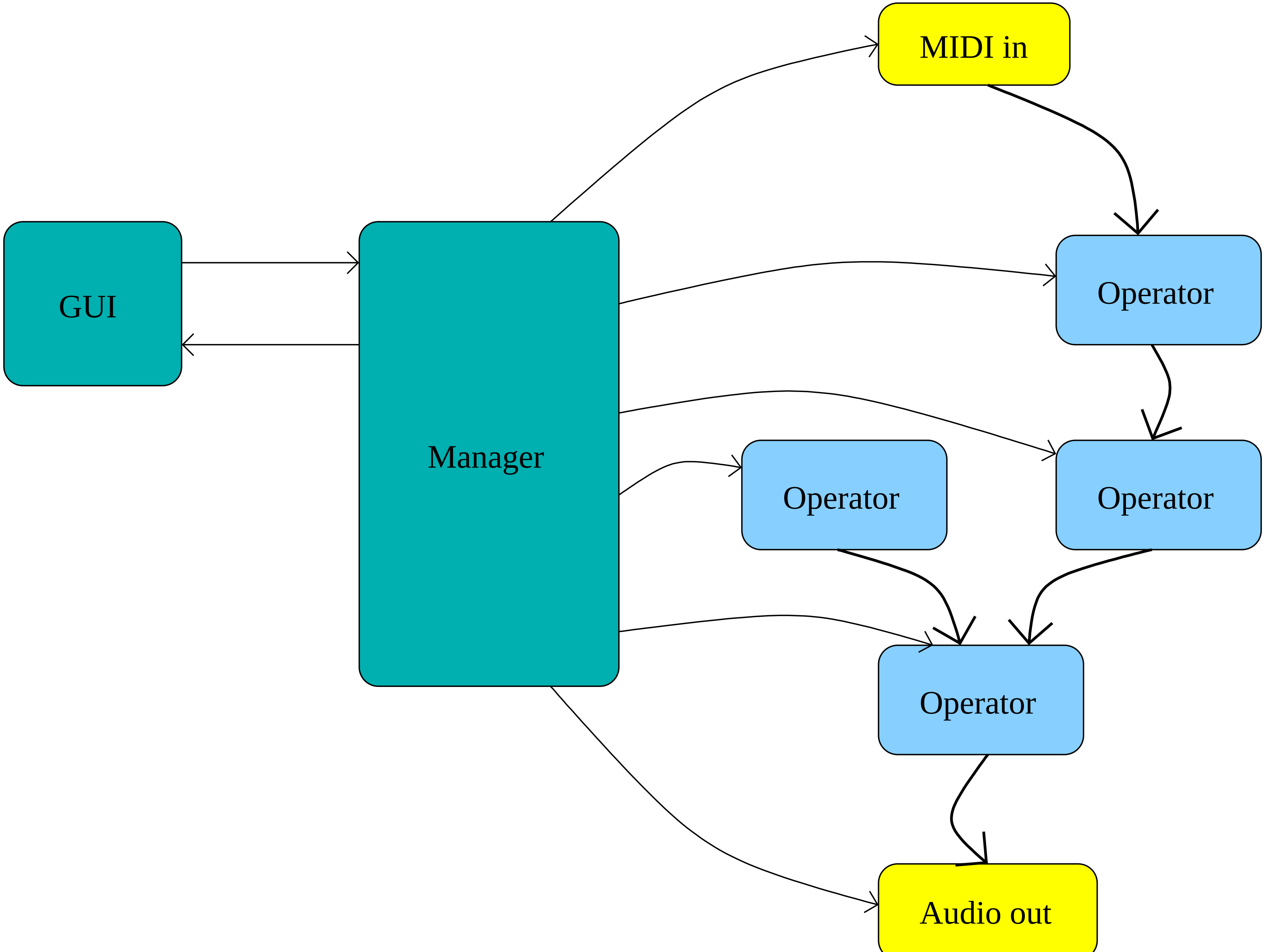
```
PROC id.component (PROC.CTL? ctl)
  PROC id (CHAN CHUNK in?, out!)
    WHILE TRUE
      CHUNK ch:
      SEQ
        in ? ch
        out ! ch
  :
  STREAM.WIRE? inw:
  STREAM.WIRE! inw.c:
  PORT.CTL? outp:
  PORT.CTL! outp.c:
  SEQ
    ctl[resp] ! reg.counts; 1; 1
    inw, inw.c := MOBILE STREAM.WIRE
    ctl[resp] ! reg.stream.in; inw.c
    outp, outp.c := MOBILE PORT.CTL
    ctl[resp] ! reg.stream.out; outp.c
    ctl[resp] ! reg.done

    CHAN CHUNK thru:
    PAR
      id (inw[c]?, thru!)
      stream.port (thru?, outp)
:
```

Replugging ports

- Input ports are mobile channels; sending end registered with a central manager process
- Output ports are buffer processes which broadcast to a set of channel ends
  - Manager has a (mobile) channel to each output port
  - Can connect, disconnect mobile channels
- MIDI and audio channels

How it all fits together



The manager

- Starts and connects components dynamically in response to GUI events
- Enforces rules about which ports can connect to which
  - Type-checking
  - Avoid cycles
- Generic; does not know what audio is, just that it's a type of port

The GUI

- Rolling your own GUI is bad, but for now. . .
- All based on vectors; scalable
- Hierachy of GUI components
  - Window contains components, which contain buttons. . .
  - Events filter down, draw lists filter back up
- Processes provided for standard GUI components (buttons, text boxes, sliders) and event filtering
- Seems to work well

Conclusions, 1

- The POP model is a natural fit for audio synthesis
- . . . even within the constraints of live programming
- We can use POP design rules to make it easier to build correct synthesis networks
- Process-oriented programs are pretty :-)

Conclusions, 2

- It's pretty easy to make existing occam-π processes dynamically pluggable
- In conjunction with other work we've done (POPExplorer, etc.), this might lead toward a useful tool
  - for teaching music to occam-π programmers?
  - for teaching occam-π to musicians?

Future work

- Better synchronisation (see Carl's work)
- Creating new components at runtime
  - Draw a network, drag a box around it
- Convert to occam code (and back?)
- Saving, deleting, . . .
- A better-designed GUI library

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Thanks for listening!

- The code is available from here:
  `http://offog.org/darcs/research/love/`
- Any questions?