Towards a New Language for Concurrent Programming CPA-2011 Fringe Session

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We've been knocking around ideas about a new occam for some time..

Some issues with occam and occam-pi as they currently exist:

perceived as an "old" language (or even dead!)

- upper-case keywords went out of fashion with BASIC
- strict indentation annoys some
- Occam-pi (as it stands) is essentially a "bolt-on" to occam
 - language is a little inconsistent or clunky in places
 - compiler breaks down easily (old code-base)
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Introducing Guppy

- deliberately not called 'occam'
- ... although we're going to use all the best bits :-)
- Still looking for a decent logo ...

- Preserving the useful features of occam/occam-pi:
 - embodiment of CSP based concurrency (though may not restrict to that alone) in the language itself
 - strict parallel usage checks: zero aliasing
- Preserving the fast execution of the resulting code:
 - no heavy run-time checks (e.g. expensive run-time typing, complex garbage collection)
 - using existing CCSP
- Targetable at just about any architecture in existence:
 - by compiling (ultimately) to LLVM (low-level virtual machine)

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- A language that other people would be happy to (and may even want to) use:
 - successes of Python and Go suggest indentation-based layout and concurrency are not distasteful
- Rapid development nothing overly cumbersome to program with respect to other languages:
 - need some genericity/flexibility in the type system
 - automatic 'SEQ' behaviour (static checks can spot likely errors)
 - may need to sacrifice some of the purity of occam to make this work..
- Automatic mobility (largely a compiler thing), with a couple of language hints thrown in to help the compiler when automatic static analysis gets too complex (or wrong).
- A proper 'string' type with UTF-8 support (32-bit 'char' probably).

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Usual primitive types:

int x #	simple signed integer
uint14 y #	# 14-bit unsigned integer
bool z #	t boolean
real64 f #	floating-point
	f string type
char c #	t unicode character
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Structured (and optionally parameterised) types:

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Named types:

define type NanoTime is uint128

Channels and Protocols

- Channels are explicitly typed with a specific protocol (as they are in occam), and sometimes with a direction
 - can be a 'null' protocol (what 'SIGNAL' is in occam-pi, more or less).
- First-class types in the language, so can be used as protocols themselves to define things like channel mobility.

- Borrow Adam's two-way protocols for defining complex communication patterns (via state machines):
 - related to the idea of session types

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chan?(chan!(int))
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```
define protocol Link
  subprotocol State1
    case
      ! start; int
      State2
  subprotocol State2
    case
      ? starting
      State3
      ? failed; int
      State1
# more states ...
State1
```

Anonymous structure (tuple) types (allowed generally as L-values):

```
chan({int,char}) c
par
    c ! {42,'x'}
    c ? {x,y}
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Abstract types, which provide an equivalent of a union and allow for recursive data structures (without having to abuse the forward-scoping rules):

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define type Tree
define type Leaf is Tree
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define type SubTree is Tree
 Tree left, right
define type Empty is default Tree
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    par
      do_walk (t.left)
      do_walk (t.right)
  Empty
           # optional
    skip
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Enumerated Types

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define enum Colours Red Green Blue



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[]uint128 data
data = [10]uint128
```

```
[8] int16 sdata
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- Array and structure elements accessed *either* with 'dot' or square brackets.
 - constant constructors for both use square brackets:



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[]int stuff = [1, 3, 6]

Barriers

Simple barrier types, as we already have in occam-pi:

```
barrier b
par  # compiler figures out which
proc_a (b)  # processes are enrolled
proc_b (b)
seq
sync b
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Also **phased barriers** for safe (CREW) access to shared state:

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```

```
define foo (barrier(2) x)
   case sync x
    0
        # in phase 0
    1
        # in phase 1
```

Function and Process Types

- For implementing (roughly) an equivalent of C's function pointer mechanism.
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```
(val int) -> int fcn
(val int, val int) -> int, int rand_fcn
(barrier, chan!(char)) proc
define type i_to_i is (val int) -> int
```

Processes / Procedures

Straightforward named blocks of code:

```
define out_10 (val int x, chan!(int) out)
  seq i = x for 10
    out ! i
    # some more code here
```

- Parameter passing uses a renaming semantics, so inlining has (logically) no effect.
- For convenience, allow the direction on channels to be specified alongside the name:

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- For convenience, allow the direction on channels to be specified alongside the name:

```
define succ (chan(int) in?, out!)
  while true
    int x
    in ? x
    out ! x+1
```

Functions

Like occam, functions must be *pure* (no side-effects):

```
define sum (val int data[]) -> int
  int res = 0
  seq i = 0 for size(data)
    res += data[i]
  return res
```

- We'll allow functions to allocate and release memory, on the assumption that the heap is passed-to and returned-from the function.
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```
define minmax (val int data[]) -> int, int
    int min = 0, max = 0
    ... code
    return min, max
```

No operator precedence (like occam), so explicit bracketing:

however, to avoid painful bracketing, assume left-to-right evaluation for the same operator

int x = (a + b) * (c + 42)

- Arithmetic overflow (and underflow) still generate run-time errors.
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int16 x, y = 42
uint8 z = 0xff
x = z
z = int16 y
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```
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```

```
int128 p = some_function (42)
real128 r = real128 trunc p
```



Support for a **conditional** expression, as found in various languages:

int v = (y == 42) ? 99 : z

Also support for **lambda** abstractions, assignable to function types:

These are dealt with at compile-time, compiled into a named function or inlined.



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```
int v = \x.(x * y) 14
define generator (chan!(i_to_i) out)
    out ! \x.(x * (x + 1))
```

Operators

- The usual set of operators as found in occam/occam-pi, with a C flavoured syntax.
- Comparison: '<', '<=', '==', '>=', '>', '!=', '<>'
- Boolean logic: '&&', '||', '><', '!'
- Bitwise: '&', '|', '^', '~'
- Arithmetic (checked): '+', '-', '*', '/', '\', '<<', '>>'
- Arithmetic (unchecked): 'plus', 'minus', 'times'

Operators

 For convenience support for increment/decrement and similar operators (really *processes*, as they cannot be used as R-values):

int x = 42 x++ # x = x + 1 x -= y # x = x - y x *= 15 # x = x * 15

Flow Control

Allow 'return' from any point inside a procedure/function.

- not a problem for modelling execution as always doable using boolean flags and 'if's
- restricted to sequential code (no outstanding parallel processes!)
- Allow 'break' inside while-loops.
 - undecided: allowing labelled loops, etc. and targetted 'break'.
- Exception handling: kept straightforward basic try/catch/finally.
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```
try
  some_routine (x, y, 42)
  some_other_routine (z)
  int8 v = int8 trunc 3.14159
catch
  report_error ()
finally
  cleanup ()
```

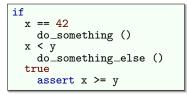
- Usual two suspects, 'skip' and 'stop':
 - use of 'skip' is largely optional indentation rules mean it's obvious when it's missing.
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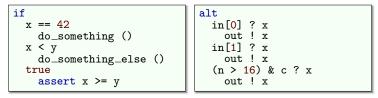
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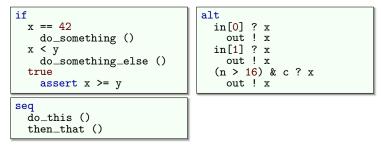
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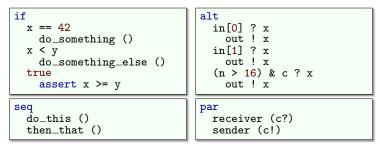
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<pre>if x == 42 do_something () x < y do_something_else () true assert x >= y</pre>	alt in[0] ? x out ! x in[1] ? x out ! x (n > 16) & c ? x out ! x
<pre>seq</pre>	par
do_this ()	receiver (c?)
then_that ()	sender (c!)

• Can nest and replicate the first four in the same way as occam.

'seq' and 'par' can omit replicator name if not needed:

```
seq for 10
   do_something ()
```

Allow a shorter version of 'if' for more convenient uses:

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if x == 42
do_something ()
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Also inline versions of 'seq' and 'par':

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screen ! 'c' -> screen ! '\n'
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Inline 'seq' ('->' read then) can also be used in 'alt' constructs for brevity:

pri alt
 c ? x -> out ! x+1
 d ? y -> stop -> skip

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An important feature for many applications

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chan?(chan!(chan?(int))) e
e ? d
d ! c
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  ICoord r
  r.x = a.x + b.x
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  return r
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return r
"-" (val a, b) -> ICoord = [a.x - b.x, a.y - b.y]
```

- Essentially operator overloading, generally a useful language feature (added to occam by Jim Moores).
 - allowed as part of type definitions for that type (as well as stand-alone).
 - must follow rules for functions (no side-effects!).

```
define type ICoord
int x, y
"+" (val a, b) -> ICoord
ICoord r
r.x = a.x + b.x
r.y = a.y + b.y
return r
"-" (val a, b) -> ICoord = [a.x - b.x, a.y - b.y]
define sq (val int v) -> int = (v * v)
define "<->" (val ICoord x, y) -> int
return sq (x.x-y.x) + sq (x.y-y.y)
```

Type Inference and Polymorphism

Allow the compiler to figure out the return type of a function (less typing for the programmer):

define foo (val int a, b)
 int pl, mi
 pl = a + b ||| mi = a - b
 return pl, mi

- Functions and procedures may have generic types.
 - specialised by the compiler for specific types:

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- Functions and procedures may have generic types.
 - specialised by the compiler for specific types:

```
define id (chan(T) in?, out!)
  while true
   T v
   in ? v -> out ! v
```

Var-Args and Run-Time Type Selection

- Disclaimer: this is not necessarily concrete yet!
- Support an explicit 'type' type, useful for run-time decision making:

```
define typeset vararg is int, byte, uint, string
define printf (chan!(char) out, string fmt, []vararg args)
    ... stuff
    seq i = 0 for size args
    case typeof args[i]
    int
        ... code for integer
    string
        ... code for string
    else
        ... unhandled cases
```

```
define main (chan!(char) screen)
    par
    # display stuff here...
    secure_college ()
```

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    # display stuff here...
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```

```
define secure_college ()
  [5]chan() left, right
  [5]chan() up, down
  par
    par i = 0 for 5
        philosopher (up[i]!, down[i]!, left[i]!, right[i]!)
    par i = 0 for 5
        fork (left[i]?, right[(i+1)\5]?)
        security (down?, up?)
```

```
define fork (chan() left?, right?)
while true
   alt
    left? -> left?
   right? -> right?
```

```
define fork (chan() left?, right?)
while true
alt
    left? -> left?
    right? -> right?
```

```
define philosopher (chan() up!, down!, fork_left!, fork_right!)
  while true
    # think ...
    down!
    fork_left! ||| fork_right!
    # eat ...
    fork_left! ||| fork_right!
    up!
```

```
define security ([]chan() downs?, ups?)
int sat = 0
val int limit = 4
while true
    alt
    alt i = 0 for size(downs)
        (sat < limit) & downs[i]?
        sat++
    alt i = 0 for size(ups)
        ups[i]?
        sat--</pre>
```

Other Things

- For two-way protocols specifically, 'chan+' and 'chan-' for client and server sides.
- Compiler extensions to allow experimentation with language structure and similar.
- A sensible **module** system for building libraries.
- Bindings to interface with existing C and occam-pi code.
- Low-level things such as 'placed' data and 'port's.
- And probably a whole lot of other things...!

State of Things

- Mostly ideas at the moment, but slowly forming into something concrete and reasonable
 - suggestions for things to add, remove or modify very welcome!
 - goal is to produce a safe concurrent language that is quick and easy to use (without compromising existing run-time performance)
- Some bits of a compiler in place in the NOCC compiler framework
 - generating mostly empty LLVM files at the moment, but in progress!