# Programming with Effect Handlers in Links

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# Programs are inherently effectful

Programs may...

- ...halt prematurely
- ...diverge
- ...be stateful (e.g. modify a global state)
- ...communicate via a network
- ...print to standard out

A pure[1] program is not much fun.

[1] By pure we mean a program that has no effects.

# Function signatures (I)

| | |
|---|---|
| $f : \mathbb{Z} \to \mathbb{Z}$ | Mathematical pure function |
| int $f$(int $x$) | C/C++ (impure) function |
| $f$ : int $\to$ int | ML (impure) function |

# Let's be explicit about effects

## Effect annotation

An effect annotation gives a static description of the potential run-time behaviour of a computation.

Benefits

- Serves as documentation (clarity)
- Compiler can apply specific optimisations
- Possible to reason more precisely about programs

# Enter the Monad

"Have you considered using a monad?"

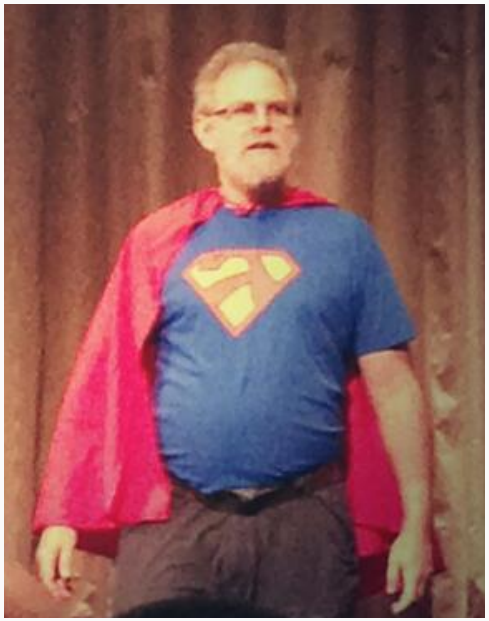

Figure 1: Philip Wadler aka. Lambda Man

- The Essence of Functional Programming (1992)
- The Marriage of Effects and Monads (1998/2003)

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| int $f$(int $x$) throws IOException | Java effect annotation |

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| $f$ : int $\to$ int | ML (impure) function |
| $f$ :: Int $\to$ IO Int | Haskell effect annotation |
| int $f$(int $x$) throws IOException | Java effect annotation |
| $f : (\text{Int}) \xrightarrow{\{Read:\text{String} \mid \rho\}} \text{Int}$ | Links effect annotations |

# Algebraic effects

Figure 2: Gordon Plotkin

Figure 3: John Power

Adequacy for Algebraic Effects (2001)

# Algebraic effects and computations

## Definition (Algebraic effect)

An algebraic effect is a collection of abstract operations. For example $State \stackrel{\text{def}}{=} \{Get : s, Put : s \to ()\}$.

## Definition (Abstract computation)

An abstract computation is composed from abstract operations.

# Effect handlers

Figure 4: Gordon Plotkin

Figure 5: Matija Pretnar

Handling Algebraic Effects (2003)

# Effect handler

## Definition (Handler)

A handler interprets an abstract computation.

## An example

Essentially, a handler pattern-matches on operations occurring in a computation $m$:

```
handler state(m) {
  case Get(k)    -> ...
  case Put(s,k)  -> ...
  case Return(x) -> ...
}
```

# WARNING

The following code examples may be reproduced at home.

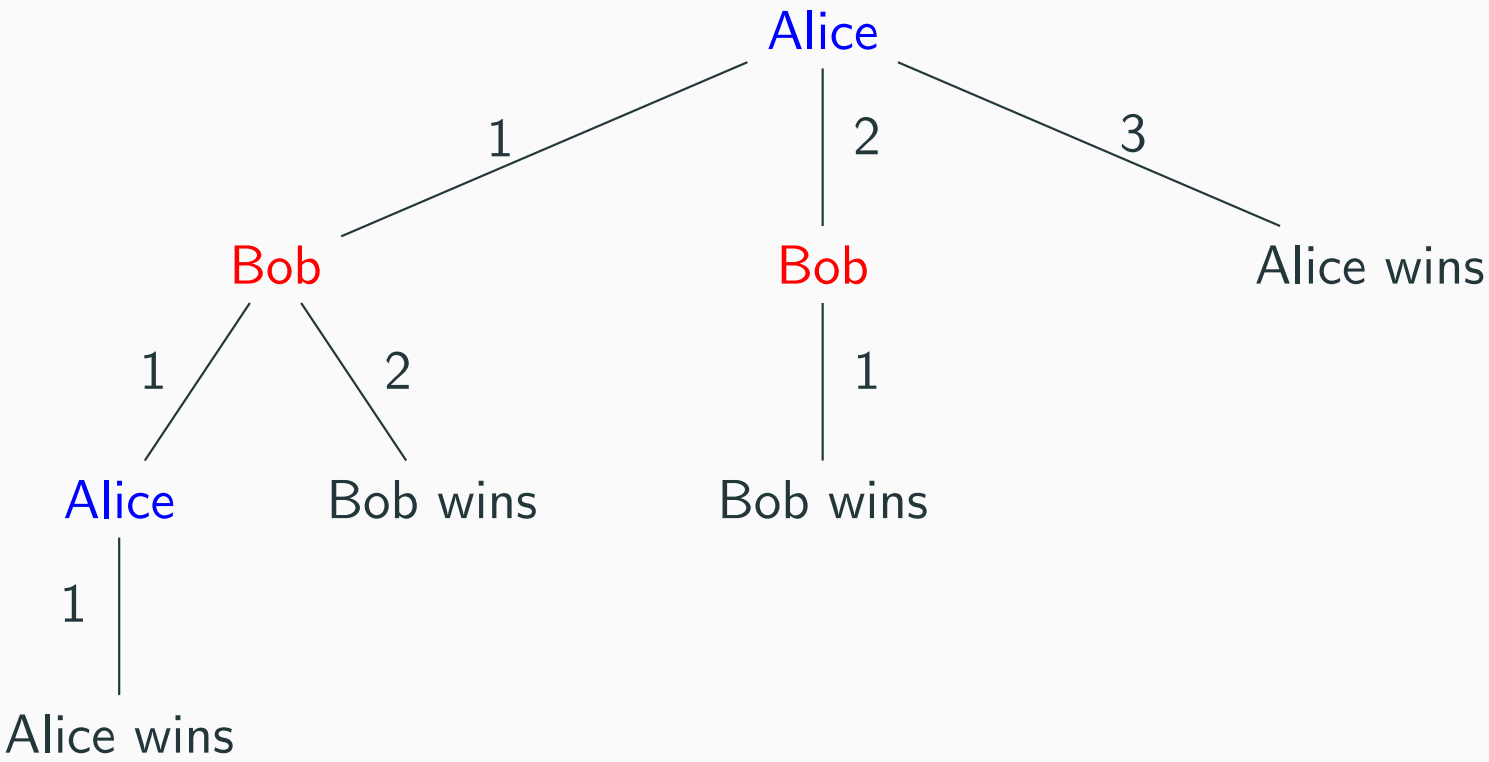
# Nim: A game with sticks

Set-up

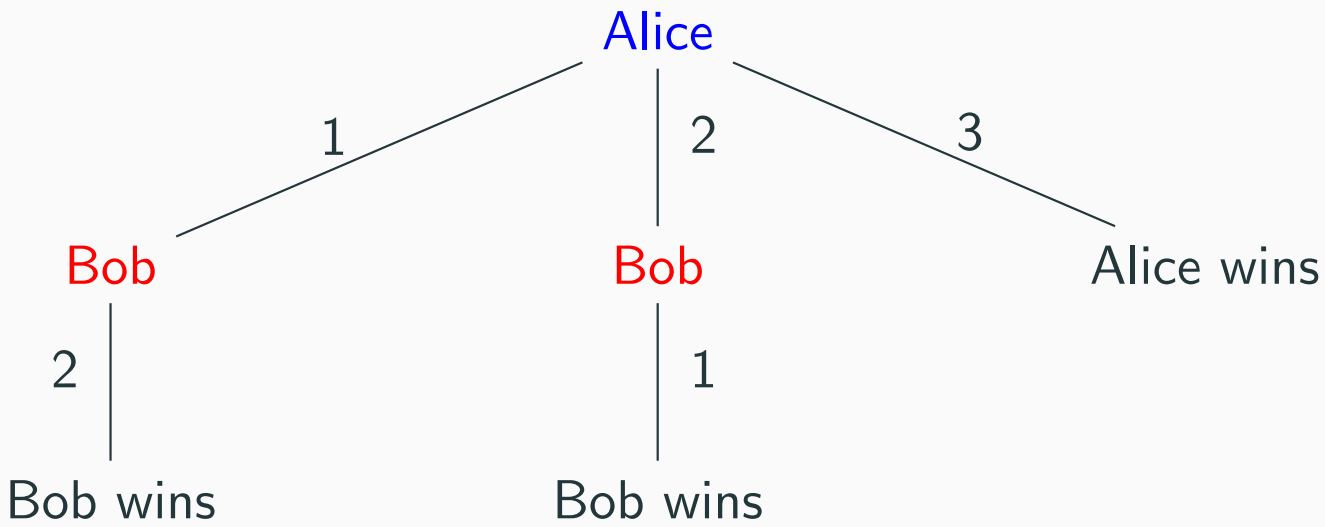
- Two players: Alice and Bob; Alice always starts.
- One heap of $n$ sticks.
- Turn-based. Each player take between 1-3 sticks.
- The one, who takes the last stick, wins.

We'll demonstrate how to encode strategic behaviour, compute game data, and cheat using handlers.

# Game tree generated by `gametree` with $n = 3$



# Game tree when Bob plays the perfect strategy, $n = 3$



# References I



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