Programming with Effect Handlers in Links

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What this talk is about

Handlers for algebraic effects provide a compelling alternative to monads as a basis for effectful programming.

- **Key idea:** Separate effect signatures from their implementation.
- **Consequent:** High-degree of modularity.

Definitions will follow later...

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.

Effectful computations (I)

$f : \mathbb{Z} \to \mathbb{Z}$	Mathematical pure function
$\text{int } f(\text{int } x)$	C/C++ (impure) function
$f : \text{int} \to \text{int}$	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?"

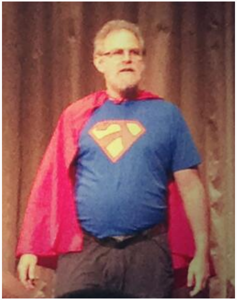


Figure 1: Philip Wadler aka. Lambda Man

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

Effectful computations (II)

$f : \mathbb{Z} \to \mathbb{Z}$	Mathematical pure function
int f(int x)	C/C++ (impure) function
f : int $\to$ int	ML (impure) function
f : Int $\to$ IO Int	Haskell effect annotation

Effectful computations (II)

$f : \mathbb{Z} \to \mathbb{Z}$	Mathematical pure function
int f(int x)	C/C++ (impure) function
f : int $\to$ int	ML (impure) function
f : Int $\to$ IO Int	Haskell effect annotation

IO can be considered an effect annotation

Effectful computations (II)

$f : \mathbb{Z} \to \mathbb{Z}$	Mathematical pure function
int f(int x)	C/C++ (impure) function
f : int $\to$ int	ML (impure) function
f : Int $\to$ IO Int	Haskell effect annotation
int f(int x) throws Exception	Java effect annotation

Great! Many monads, many effects

A couple of monads and their "effect interpretation"

IO a	May perform I/O, returns a
Reader r a	May read from r, returns a
Writer w a	May write to w, returns a
State s a	May read/write some state s, returns a
Maybe a	May fail, returns a on success

Sadly, monads do not compose well.

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 $\mathit{Choice} \stackrel{\text{def}}{=} \{\mathit{Choose} : \mathsf{Bool}\}$.

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 choice(m) {
  case Choose(k) -> ...
  case Return(x) -> ...
}
```

WARNING

The following code examples may be reproduced at home.

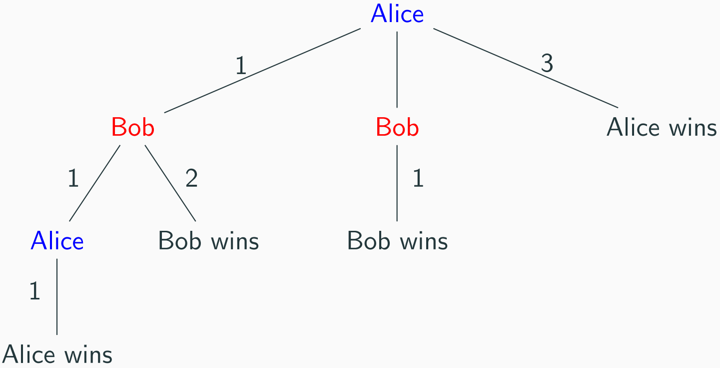
Nim: A game with sticks

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 `mtGen` with $n = 3$



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