Programming with Effect Handlers in Links

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Programs are inherently effectful

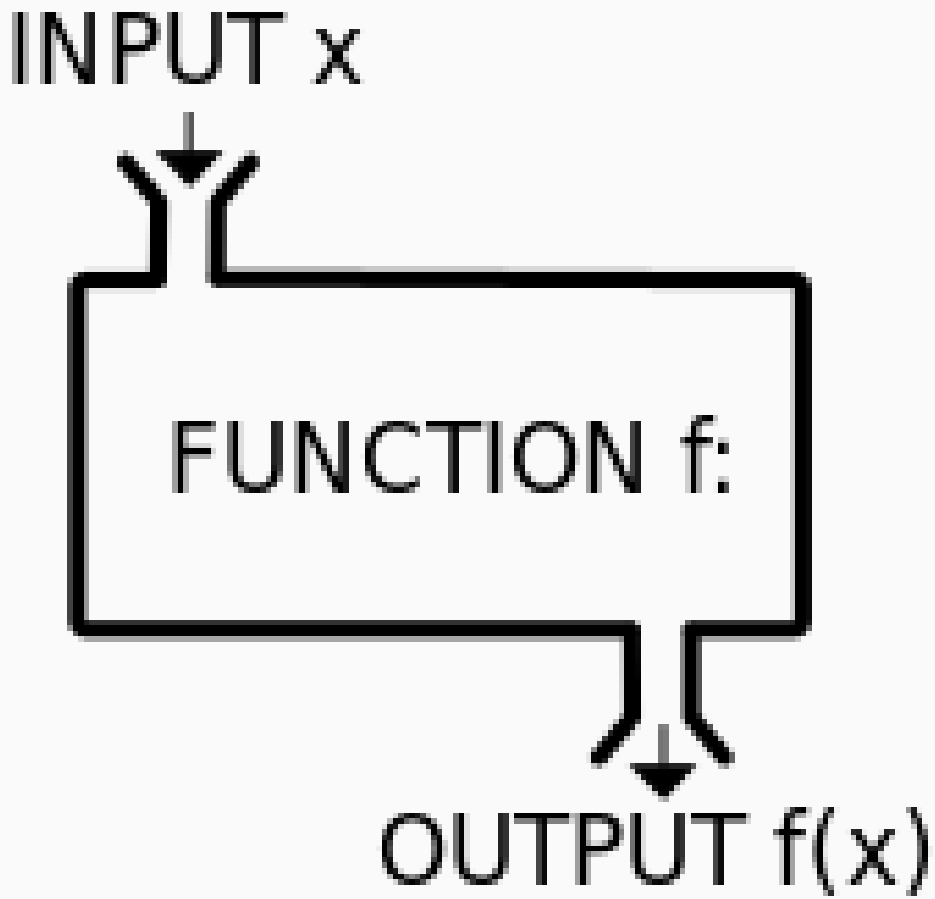
Programs may...

- ...halt prematurely
- ...diverge
- ...be stateful (e.g. allocating memory, throwing exceptions)
- ...communicate via a network
- ...print to standard out

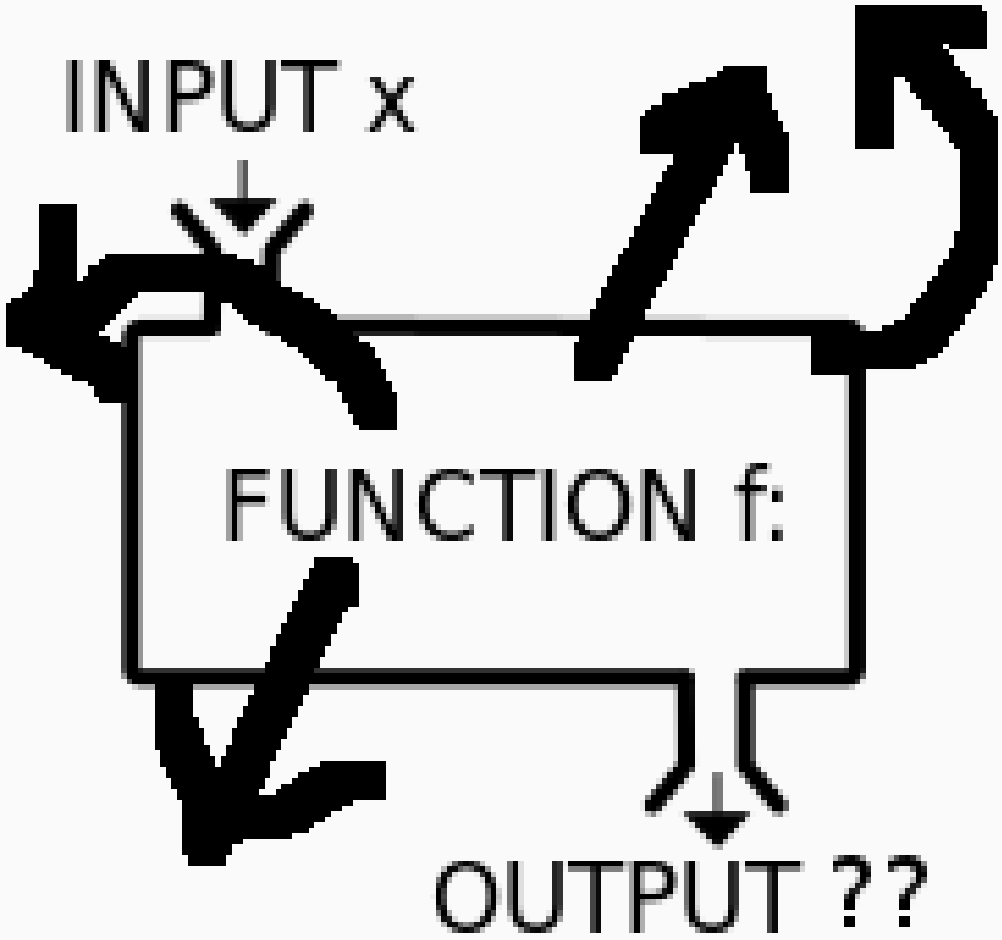
A pure[1] program is not much fun.

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

Pure vs. impure



Pure vs. impure



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?"

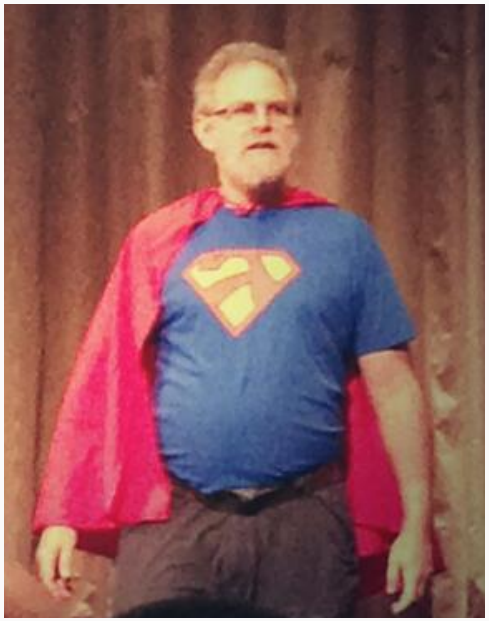


Figure 1: Philip Wadler aka. Lambda Man

- The Essence of Functional Programming (1992)
- The Marriage of Effects and Monads (with Peter Thiemann, 2003)

Function signatures (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

Function signatures (II)

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f :: Int $\to$ IO Int	Haskell effect annotation
int f(int x) throws IOException	Java effect annotation

Function signatures (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 IOException	Java effect annotation
f : (Int) $\xrightarrow{\{Read:\text{String}, Write:\text{String}\to()\}}$ Int	Links effect annotation

Algebraic effects

Algebraic effects give us a modular way of describing multiple 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

Effect handlers assign a particular meaning (semantics) to algebraic effects.

Figure 4: Gordon Plotkin

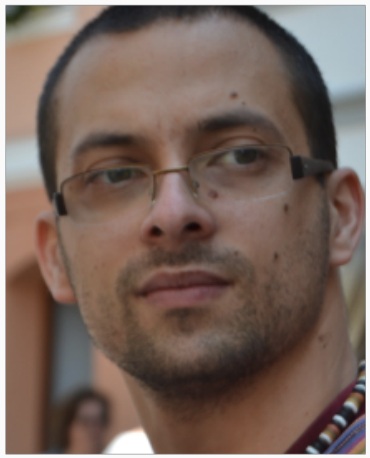


Figure 5: Matija Pretnar

Handling Algebraic Effects (2003)

Effect handler

Definition (Handler)

A handler is an interpreter for abstract computations.

An example (Links style handler)

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

```
handler state(m) {
  case Get    -> ...
  case Put(s) -> ...
  ...
}
```

Recall $State \stackrel{\text{def}}{=} \{Get : s, Put : s \to ()\}$

Notion of computation in Links

In Links, we define the type of (handler compatible) computations as

$$Comp(E, a) \stackrel{\text{def}}{=} () \xrightarrow{E} a,$$

where E is an effect signature, and a is the return type of the computation. In other words, computations are thunks.

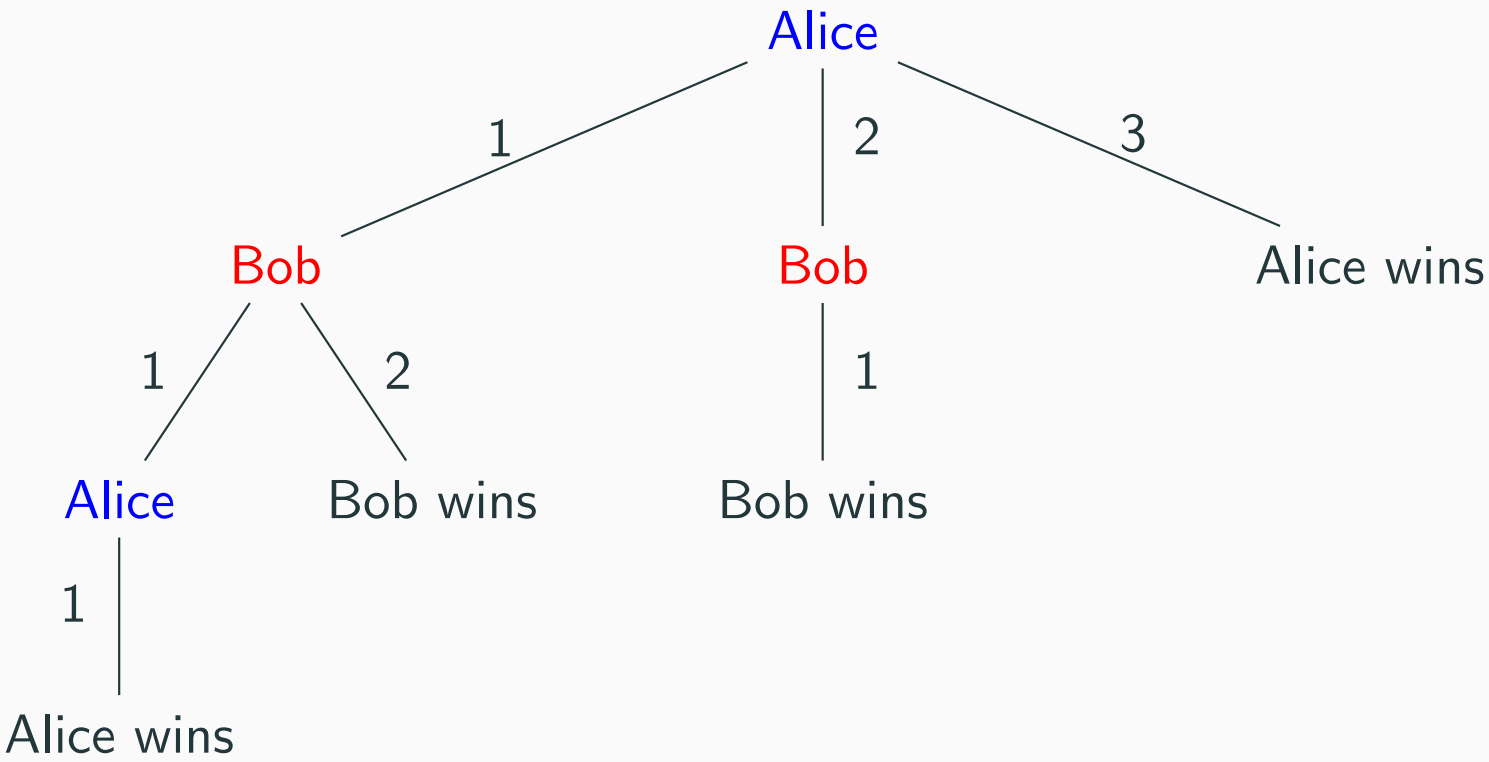
Handlers in action: Nim – A game with sticks

Set-up

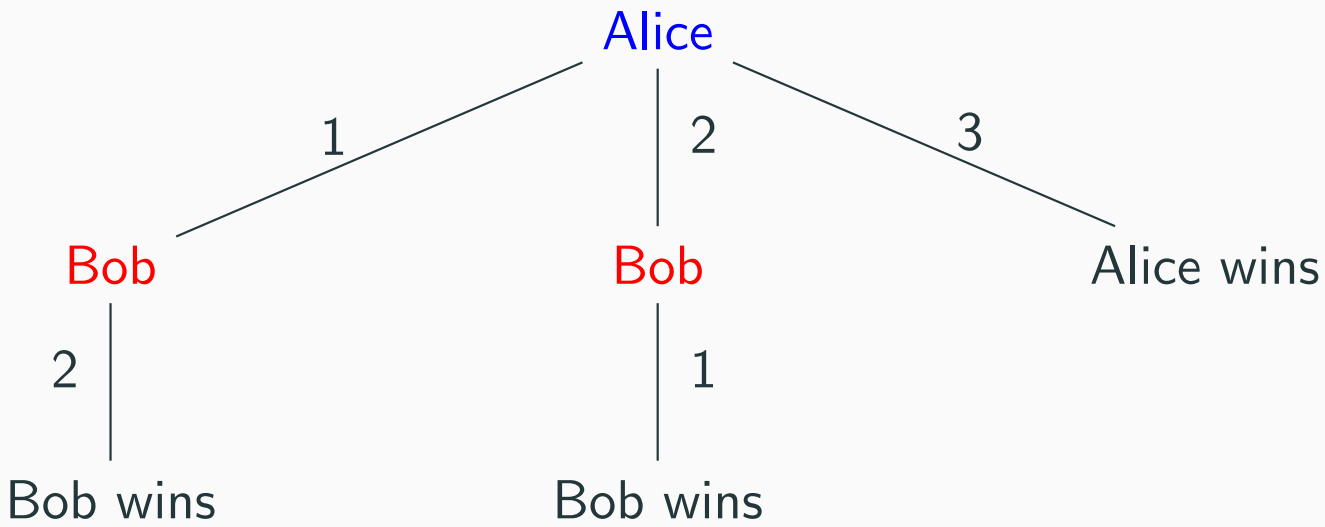
- Two players: Alice and Bob; Alice always starts.
- One heap of n sticks.
- Turn-based. Each player take between 1-3 sticks.
- The one, who takes the last stick, wins.

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, $n = 3$



Conclusion

Handlers for algebraic effects give us a highly modular basis for effectful programming.

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

References I


Gordon D. Plotkin and Matija Pretnar.
Handling algebraic effects.
Logical Methods in Computer Science, 9(4), 2013.


Philip Wadler, Sam Lindley, Garrett Morris, et al.
Links: Linking theory to practice for the web.
`http://groups.inf.ed.ac.uk/links/`, 2005.


Ohad Kammar, Sam Lindley, and Nicolas Oury.
Handlers in action.
In *ICFP'13*, pages 145–158, 2013.


Philip Wadler and Peter Thiemann.
The marriage of effects and monads.
ACM Trans. Comput. Log., 4(1):1–32, 2003.

References II

Philip Wadler.
The essence of functional programming.
In *Proceedings of the 19th ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages*, POPL '92, pages 1–14, New York, NY, USA, 1992. ACM.

Gordon D. Plotkin and John Power.
Adequacy for algebraic effects.
In *Foundations of Software Science and Computation Structures, 4th International Conference, FOSSACS 2001 Held as Part of the Joint European Conferences on Theory and Practice of Software, ETAPS 2001 Genova, Italy, April 2-6, 2001, Proceedings*, pages 1–24, 2001.