COMP3141

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CSE, UNSW (and Data6

Term 2 2019

Effects

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// exception effect
throw new Exception();
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Example (Non-termination)

```
// infinite loop
while (1) {};
```

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Internal vs. External Effects

External Observability

An *external* effect is an effect that is observable outside the function.
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Are memory effects *external* or *internal*?

Answer: Depends on the scope of the memory being accessed. Global variable accesses are *external*.

Purity

A function with no external effects is called a *pure* function.

Pure functions

A *pure function*

`a -> b` is *fully* … `a` to the codomain type …

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Question: Are Haskell functions pure?

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Despite the impurity of Haskell functions, we can often reason as though they are pure. Hence we call Haskell a purely functional language.

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We can't, in general, reason equationally about effectful prog

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Efficiency?

All that copying might seem expensive, but by using tree data structures, we can usually reduce the cost to an $\mathcal{O}(\log n)$ overhead.

State Passing

Example (Labelling Nodes)

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data Tree a = Branch a (Tree a) (Tree a) | Leaf
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Given a tree, label ea

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label :: Tree () -> T
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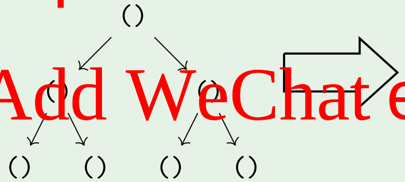

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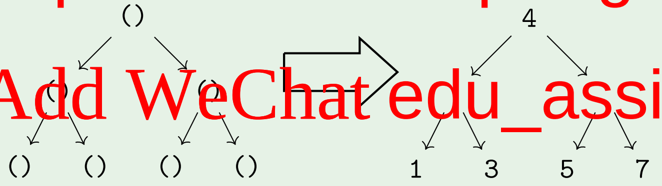

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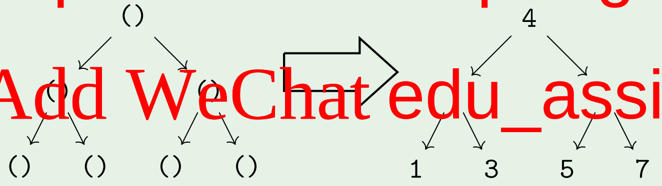

Let's use a data type to simplify this!

State

`newtype State s a` = A procedure that, manipulating some state of type `s`, returns `a`

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State Operations

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get :: State s s
put :: s -> State s ()
pure :: a -> State s a
evalState :: State s a -> s -> a
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Sequential Composition

do blocks:

```
(>>) :: St
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The 2nd step can depen

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do x <- get
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get >>= \x -> pure (x + 1)
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Example

Implement `modify`:

```haskell
(s -> s) -> State s ()
```

And re-do the tree labelling.

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State Implementation

The State type is essentially implemented as the same state passing we did before!

```
newtype State s a = State (s -> (s,a))
```

Example

Let's implement e

Caution

In the Haskell standard library mtl, the State t ntly differently, but the implementation essentially works the same way.

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Haskell's approach

Pure by default. Effectful when necessary.

The IO Type

A procedure that performs some side effects, returning a result of type a is written as IO a

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World interpretation

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```
(>>=) :: IO a -> (a -> IO b) -> IO b
pure  :: a -> IO a

getChar :: IO Char
readLine :: IO String
putStrLn :: String -> IO ()
```

Infectious IO

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But it returns an `IO` procedure as well.

Conclusion

The moment you use an `IO` procedure in a function, `IO` shows up in the types, and you can't get rid of it!

If a function makes use of `IO` effects directly or indirectly, it will have `IO` in its type!

Haskell Design Strategy

We ultimately "run" `IO` procedures by calling them from `main`:

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main :: IO ()
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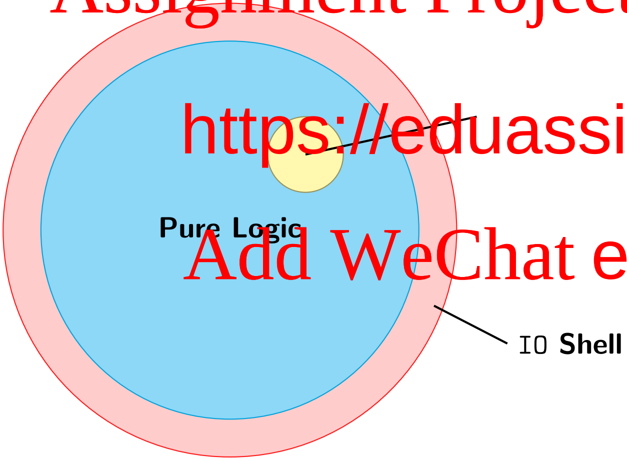

Examples

Example (Triangles)

Given an input nu n.

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Example (Maz

Design a game that reads in a $n \times n$ maze from a fil
$(0, 0)$ and must reach position $(n-1, n-1)$ to win ut
to move the player around the maze.

Benefits of an IO Type

- Absence of effects makes type system more informative:
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- Absence of effects makes type system more informative:
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- It is easier to reason about pure code and it is easier to test:
  - Testing is local, doesn't require complex set-up and tea
  - Reasoning is local, doesn't require state invariants.
  - Type checking leads to strong guarantees.

Mutable Variables

We can have honest-to-goodness mutability in Haskell, if we really need it, using `IORef`.

```haskell
data IORef a
newIORef :: a -> IO (
readIORef :: IO
writeIORef :: IORef a -> a -> IO ()
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Example (Effectful Average)

Average a list of numbers using IORefs.

Mutable Variables, Locally

Something like averaging a list of numbers doesn't require external effects, even if we use mutation internally.

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data STRef s a
newSTRef :: a -> ST (
readSTRef :: ST
writeSTRef :: S
runST :: (forall s. ST s a) -> a
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The extra s parameter is called a state thread, that ensures don't leak outside of the ST computation.

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Note

The ST type is not assessable in this course, but it is useful sometimes in Haskell programming.

QuickChecking Effects

QuickCheck lets us test `IO` (and `ST`) using this special property monad interface:


```
monadicIO :: PropertyM IO () -> Property
pre       :: Bool -> PropertyM IO ()
assert    :: Bool -> Prop
run       :: IO a -> PropertyM IO a
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Do notation and s[illegible]st as with State s and IO procedures.

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Let's test that our IO average function works like the n

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Example (Testing `average`)

Let's test that our `IO` average function works like the n

Example (Testing `gfactor`)

Let's test that the GNU `factor` program works correctly!

Homework

1. New exerci
2. Last week's
3. This week's quiz is due the Friday after the following Frida