



Real-World Haskell

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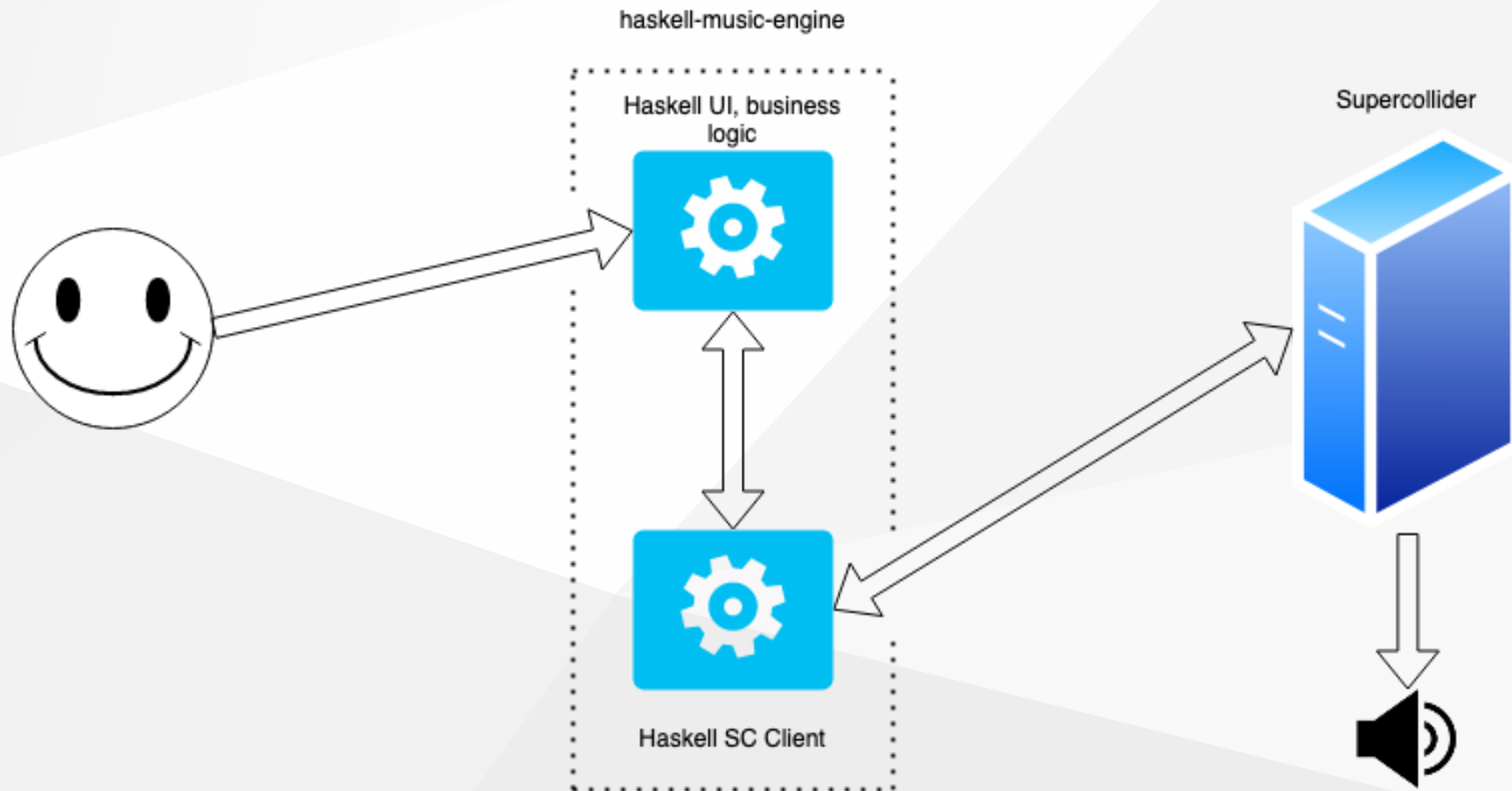
A bit about me

- Full time Haskeller at [Runtime Verification, Inc.](https://runtimeverification.com/)
- Our project: A symbolic execution engine and automated prover for the K language
 - over 150k lines of open-source Haskell code:
<https://github.com/runtimeverification/haskell-backend>
 - more about the K language and framework:
<https://kframework.org/>

Today's Presentation

1. Demo: a Haskell program which interacts with the outside world
2. Theory: language constructs which allow this interaction
3. Practice: let's see how these ideas apply in our demo program!

haskell-music-engine



What do we need to write a program which actually *does* something?

- impure languages let you do whatever you want whenever you want
- pure languages require you to *really* think about what effects your program will have
- most programs require:
 - interaction with the "outside world"
 - partiality and exceptions
 - environments
 - state

Haskell Input and Output

The "magical" Haskell type: `data IO a`

```
main :: IO ()
main = do
    name <- getLine
    putStrLn ("Hello " <> name)
```

- `getLine :: IO String`
- `putStrLn :: String -> IO ()`
- do-notation: sugar for effectful computations which can be sequenced (a.k.a. monads 🤔)

Recap: the Maybe type

Type which denotes partiality: `data Maybe a = Nothing | Just a`

```
findMonthlyDepartmentSalary
  :: [(Int, String)] -- employee id to department name
  -> [(String, Double)] -- name to yearly average salary
  -> Int -- employee id
  -> Maybe Double -- average monthly salary
findMonthlyDepartmentSalary nameTable salaryTable empId =
  case lookup empId nameTable of
    Just depName ->
      case lookup depName salaryTable of
        Just salary -> salary `divideDouble` 12.0
        Nothing -> Nothing
    Nothing -> Nothing
```

Maybe as an "effect"

- `Maybe` is an instance of `Monad` => we can use do-notation!

```
findMonthlyDepartmentSalary'
  :: [(Int, String)] -- employee id to department name
  -> [(String, Double)] -- name to yearly average salary
  -> Int -- employee id
  -> Maybe Double -- average monthly salary
findMonthlyDepartmentSalary' nameTable salaryTable empId = do
  depName <- lookup empId nameTable
  salary <- lookup depName salaryTable
  return (salary `divideDouble` 12.0)
```

- no more spaghetti code 🎪

Modelling Exceptions (1)

- Remember the `Either` type: `data Either e a = Left e | Right a`
- `Either` is also an instance of `Monad`, it's basically just like `Maybe` but the error value contains more information => good for modelling exceptions
- In practice, we usually use a type called `Except`, which is practically equivalent to `Either`; we'll see more about that later

Modelling Exceptions (2)

```
safeDivision :: Double -> Double -> Except String Double
safeDivision x1 x2 = do
    unless (x2 /= 0.0) (throwE "Cannot divide by 0!")
    return (x1 `divideDouble` x2)
```

```
procedure :: Double -> Double -> Except String Double
procedure defaultValue input = do
    let number1 = doSomething1 input
        number2 = doSomething2 input
    catchE
        (safeDivision number1 number2)
        (\errorMsg -> do
            -- maybe I'd like to log this message?
            return defaultValue
        )
```

Modelling State (1)

- In real life, things are usually stateful
- How can we encode state into Haskell? Essentially, our functions need to "carry" some additional, readable and writable info
- Something like `f :: b -> s -> (s, a)`, in order to keep things tidy, we wrap this in a newtype:

```
newtype State s a = State { runState :: s -> (s, a) }
```

- We'll have `f :: b -> State s a`

Modelling State (2)

```
data Switch = On | Off

doubleOnce :: Int -> Switch -> (Switch, Int)
doubleOnce x switch =
  case switch of
    On -> (Off, x * 2)
    Off -> (On, x)
```

Modelling State (3)

```
data Switch = On | Off

doubleOnce :: Int -> State Switch Int
doubleOnce x = do
  switch <- get
  case switch of
    On -> do
      put Off
      return (x * 2)
    Off -> do
      put On
      return x
```

Pretty nice, but...

...there's not much we can do with just one kind of effect.

Also, a bit more about what's going on here:

- imperative programming can be *encoded* into plain Haskell
- do-notation provides a nice abstraction over this encoding
- you'll learn more about this when you reach the lesson on monads

Other effects we haven't talked about:

- Reader, Writer
- non-determinism (lists)
- ...and a whole world of other useful types 😊

Combining Effects (1)

We want to:

- have several effects inside the same function
- be able to use that nice do-notation

One solution: *monad transformers*.

They are types which allow you to stack several monads on top of each other, and are also themselves monads*.

(*) in general, monads don't always compose

Combining Effects (2)

1. haskell-music-engine: a more in-depth look

2. Further reading:

- transformers package:
<https://hackage.haskell.org/package/transformers>
- mtl package:
<https://hackage.haskell.org/package/mtl>

Thank you!