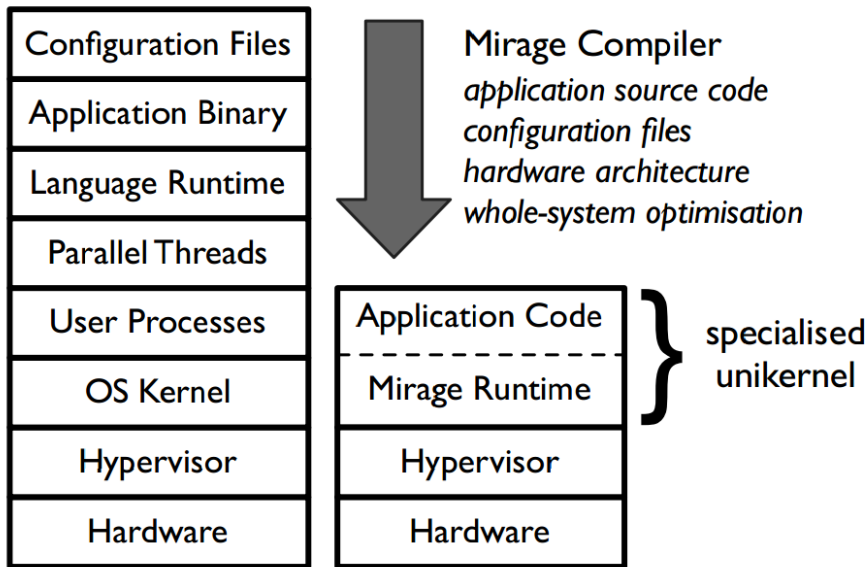


# Modularity and Backpack

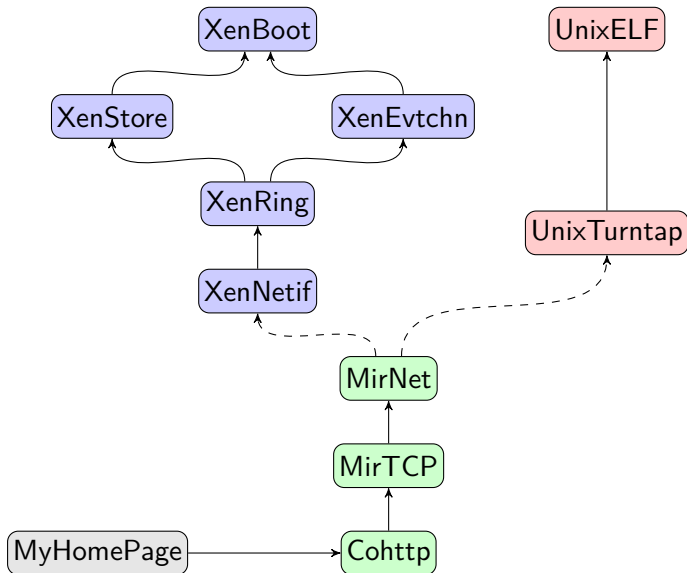
Maciek Makowski (@mmakowski)

26th January 2015

# MirageOS



# MirageOS



# Exhibit 1

## MirageOS

*The compiler heavily emphasises static type checking, and the resulting binaries are fast native code with no runtime type information and the module system is among the most powerful in a general-purpose programming language in terms of permitting flexible and safe code reuse and refactoring.*

- Technical Background of MirageOS

# ML Modules

## Structures

```
structure IntInteger =  
  struct  
    type integer = int  
    val zero = 0  
    fun succ n = n + 1  
    fun add a b = a + b  
    fun mul a b = a * b  
  end
```

# ML Modules

## Signatures

```
signature INTEGER =  
  sig  
    type integer  
    val zero: integer  
    val succ: integer -> integer  
    val add: integer -> integer -> integer  
    val mul: integer -> integer -> integer  
  end
```

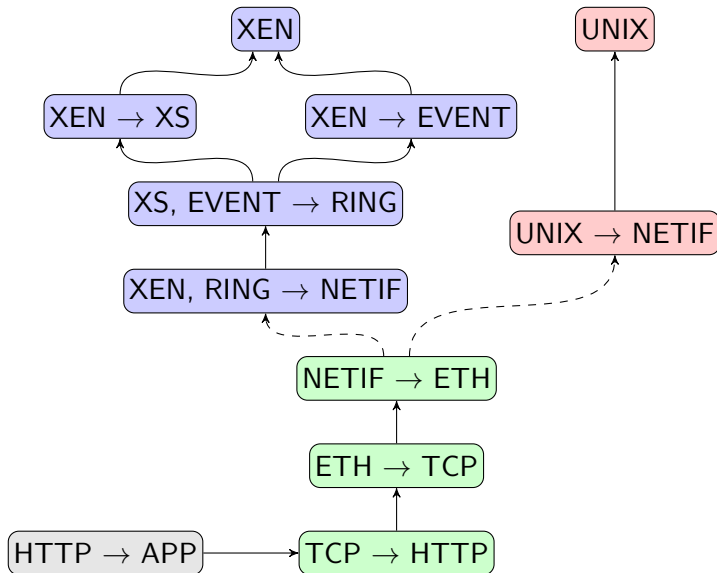
# ML Modules

## Functors

```
functor RationalFun(l: INTEGER) =  
  struct  
    type rational = l.integer * l.integer  
    fun nom (n, _) = n  
    fun denom (_, d) = d  
    fun add (n1, d1) (n2, d2) =  
      (l.add (l.mul n1 d2) (l.mul n2 d1),  
       l.mul d1 d2)  
  end
```

```
structure IntRational = RationalFun(IntInteger)
```

# ML Modules





# Scala

trait ~ signature

```
trait IntegerSig {  
  type Integer  
}
```

object ~ structure

```
object IntInteger extends IntegerSig {  
  type Integer = Int  
}
```

class ~ functor

```
class RationalFun[I <: IntegerSig](i: I) {  
  type Rational = (I#Integer, I#Integer)  
}
```

## Exhibit 2

tagstream-conduit

```
data Dec builder string = Dec
{ decToS      :: builder -> string
, decBreak    :: (Char -> Bool) -> string ->
                  (string, string)
, decBuilder  :: string -> builder
, decDrop     :: Int -> string -> string
, decEntity   :: string -> Maybe string
, decUncons   :: string -> Maybe (Char, string)
}
```

# Exhibit 3

tagsoup

```
class (Typeable a, Eq a) => StringLike a where  
  empty      :: a  
  cons       :: Char -> a -> a  
  uncons     :: a -> Maybe (Char, a)  
  toString   :: a -> String  
  fromString :: String -> a  
  — [...] ]
```

# Backpack

## Modules

```
module IntegerInt where
```

```
type Integer = Int
```

```
zero = 0
```

```
succ = (+1)
```

```
add = (+)
```

```
mul = (*)
```

# Backpack

## Signatures

```
module IntegerSig where  
  
data Integer  
  
zero  :: Integer  
succ  :: Integer  
add   :: Integer -> Integer -> Integer  
mul   :: Integer -> Integer -> Integer
```

# Backpack

## Modules

```
module Rational where  
  
import qualified IntegerSig as I  
  
data Rational = R I.Integer I.Integer  
  
nom (R n _) = n  
denom (R _ d) = d  
add (R n1 d1) (R n2 d2) =  
  R (I.add (I.mul n1 d2) (I.mul n2 d1))  
    (I.mul d1 d2)
```

# Backpack

Cabal packages

Integer implementation package

<b>name:</b> integer-int
<b>exposed-modules:</b> IntegerInt

# Backpack

Cabal packages

## Integer signature package

<b>name:</b>	integer-sig
<b>version:</b>	1.0
<b>indefinite:</b>	True
<b>exposed-signatures:</b>	IntegerSig



# Backpack

Cabal packages

Rational “functor” package

<b>name:</b>	rational
<b>indefinite:</b>	True
<b>build-depends:</b>	integer-sig-1.0
<b>exposed-modules:</b>	Rational

# Backpack

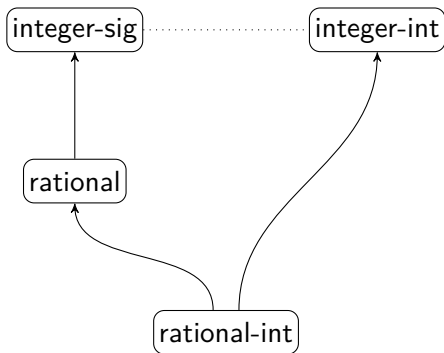
Mixing in

Rationals based on Integers

```
name:                rational-int  
build-depends:  
    integer (IntegerInt as IntegerSig),  
    rational  
reexported-modules: Rational as RationalInt
```

# Backpack

Package hierarchy



# Instantiation Semantics

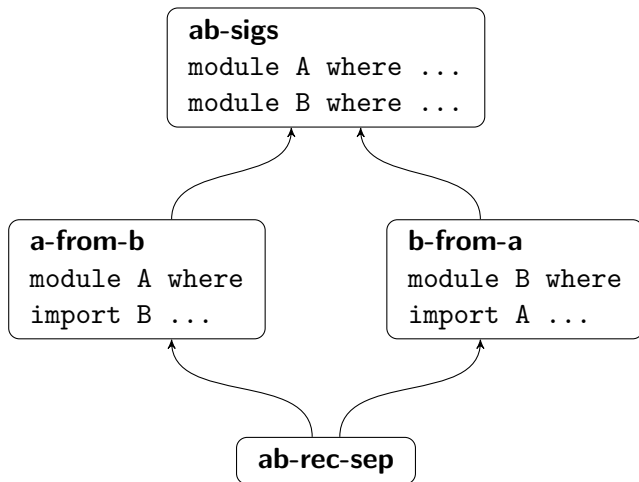
```
functor RationalFunD(I: INTEGER) =  
  struct  
    datatype rational =  
      R of I.integer * I.integer  
    val zero = R (I.zero, I.succ I.zero)  
  end  
structure R1 = RationalFunD(IntInteger)  
structure R2 = RationalFunD(IntInteger)
```

Is R1.rational the same type as R2.rational?

- ▶ *generative*: no
- ▶ *applicative*: yes

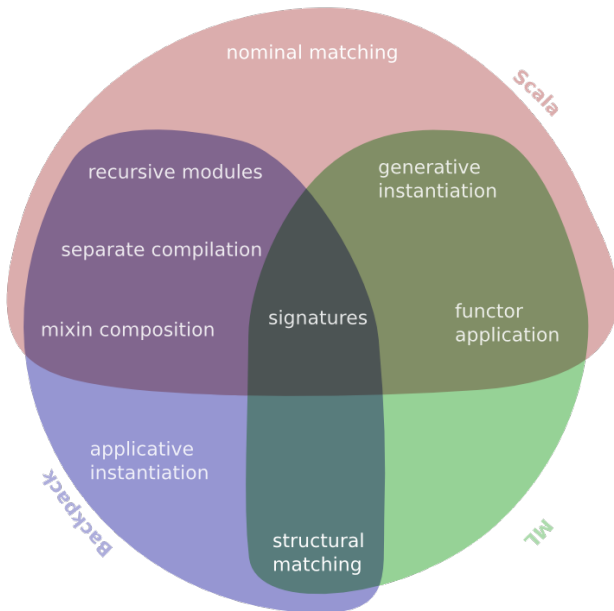
# Backpack

## Recursive linking



# Module Systems

## Features



# More

- ▶ [blog.ezyang.com](http://blog.ezyang.com) (including comments)
- ▶ Edward Yang's *Haskell Implementor's Workshop* talk
- ▶ The Backpack paper
- ▶ papers by Derek Dreyer (e.g. MixML)