Background – Type Classes (1B)

Young Won Lim
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Please send corrections (or suggestions) to youngwlim@hotmail.com.

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Based on

http://learnyouahaskell.com/making-our-own-types-and-typeclasses#the-functor-typeclass

http://learnyouahaskell.com/functors-applicative-functors-and-monoids

Haskell in 5 steps
https://wiki.haskell.org/Haskell_in_5_steps

Typeclasses and Instances

Typeclasses are like interfaces

defines some behavior
comparing for *equality*
comparing for *ordering*
enumeration

Instances of that **typeclass**
types possessing such behavior

such *behavior* is defined by

- **function definition**
- function **type declaration** only

a function definition

```
(==) :: a -> a -> Bool
x == y = not (x /= y)
```

- **a type declaration**

a function type

```
(==) :: a -> a -> Bool
```

- **a type declaration**

A function definition can be **overloaded**

http://learnyouahaskell.com/making-our-own-types-and-typeclasses#the-functor-typeclass

Typeclasses and Type

Typeclasses are like interfaces

defines some behavior
- comparing for *equality*
- comparing for *ordering*
- *enumeration*

Instances of that **typeclass**

types possessing such behavior

a **type** is an **instance** of a **typeclass** implies

the function types declared by the **typeclass**
are defined (implemented) in the **instance**

so that we can use the functions
that the **typeclass** defines with that **type**

No relation with classes in Java or C++

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Car Type Example

the Eq typeclass

defines the functions **==** and ***/=***

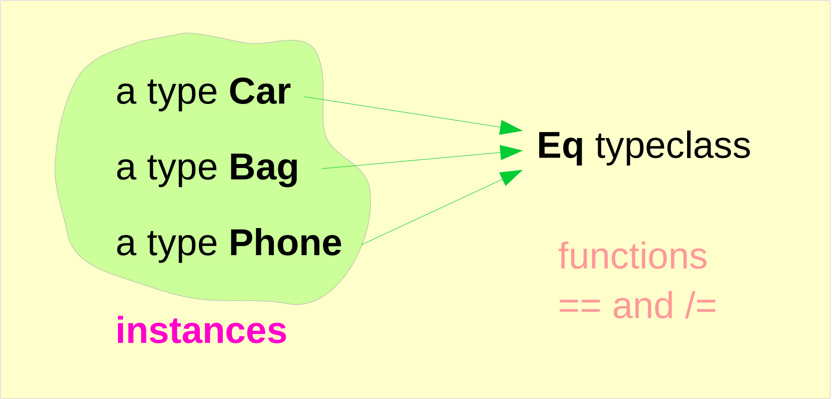
a type Car

comparing two cars c1 and c2 with the equality function ==

The Car type is an **instance** of Eq **typeclass**

Instances : various types

Typeclass : a group or a class of these similar types



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TrafficLight Type Example (1)

```
class Eq a where
    (==) :: a -> a -> Bool          - a type declaration
    (/=) :: a -> a -> Bool          - a type declaration
    x == y = not (x /= y)           - a function definition
    x /= y = not (x == y)           - a function definition
```

```
data TrafficLight = Red | Yellow | Green
```

```
instance Eq TrafficLight where
    Red    == Red    = True
    Green  == Green  = True
    Yellow == Yellow = True
    _ == _           = False
```

```
ghci> Red == Red
True
ghci> Red == Yellow
False
ghci> Red `elem` [Red, Yellow, Green]
True
```

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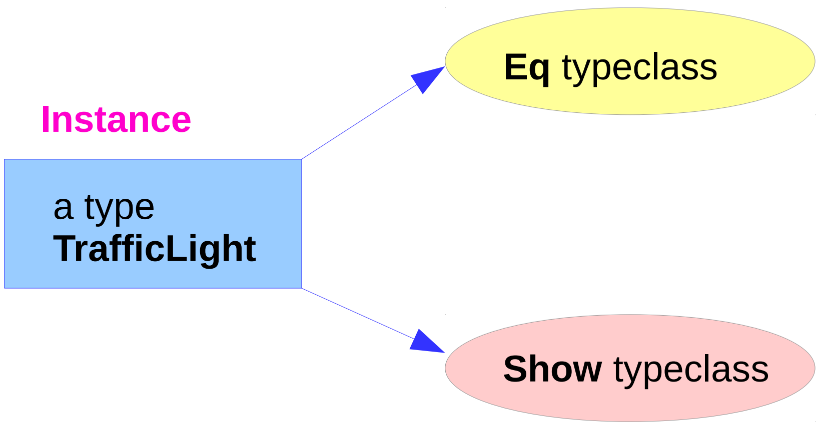
TrafficLight Type Example (2)

```
class Show  a where
   show :: a  -> String
   * * *
```

- a type declaration

```
data TrafficLight = Red | Yellow | Green
```

```
instance Show TrafficLight where
    show Red = "Red light"
    show Yellow = "Yellow light"
    show Green = "Green light"
```




```
ghci> [Red, Yellow, Green]
[Red light,Yellow light,Green light]
```

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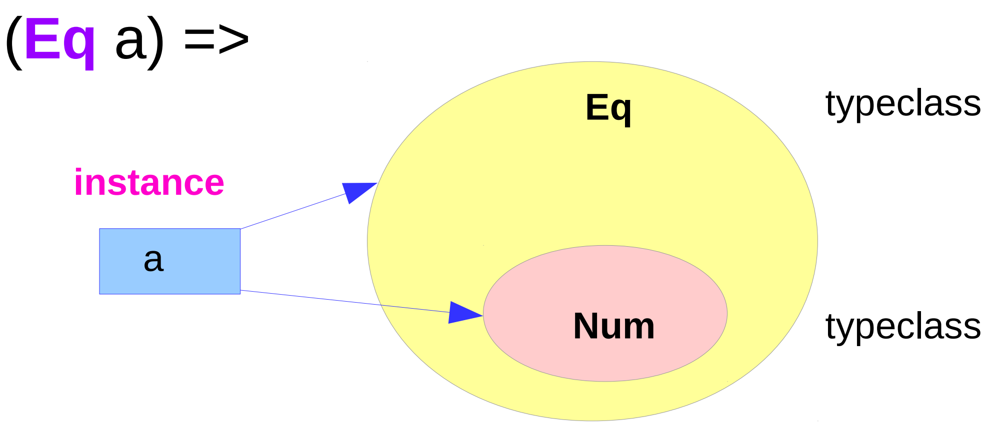
Class Constraints

```
class (Eq a) => Num a where
  ...
```

```
class Num a where
  ...
```



Num : a subclass of **Eq**

class constraint on a class declaration

an instance of **Eq**
before being an instance of **Num**

the required function bodies can be defined in

- the class declaration
- an instance declarations,

we can safely use == because a is a part of **Eq**

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Class Constraints : class & instance declarations

class constraints in **class declarations**

to make a typeclass a **subclass** of another typeclass

subclass

```
class (Eq a) => Num a where
    …
```

class constraints in **instance declarations**

to express **requirements** about the contents of some type.

requirements

```
instance (Eq x, Eq y) => Eq (Pair x y) where
   Pair x0 y0 == Pair x1 y1 = x0 == x1 && y0 == y1
```

http://cmsc-16100.cs.uchicago.edu/2016/Lectures/07-type-classes.php

http://learnyouahaskell.com/making-our-own-types-and-typeclasses#the-functor-typeclass

Class constraints in instance declaration examples

```
instance (Eq m) => Eq (Maybe m) where
    Just x    ==  Just y        =     x == y   ⟸ Eq m
    Nothing  ==  Nothing       =     True
          _ == _               =     False
```

```
instance (Eq x, Eq y) => Eq (Pair x y) where
    Pair x0 y0 == Pair x1 y1 = x0 == x1 && y0 == y1
         ⇧                        ⇧           ⇧
    Eq (Pair x y)                Eq x        Eq y
```

Derived instance

http://learnyouahaskell.com/making-our-own-types-and-typeclasses#the-functor-typeclass

A Concrete Type and a Type Constructor

a : a concrete type

Maybe : not a concrete type
: a type constructor that takes one parameter
produces a concrete type.

Maybe a : a concrete type

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Polymorphism in Haskell

Haskell's combination of

- purity
- higher order functions
- parameterized algebraic data types
- typeclasses

allows us to implement **polymorphism** on a much higher level

Types in Haskell

- don't have to think about types belonging to a big hierarchy of types
- think about what the types can act like
- and then connect them with the appropriate typeclasses

Example:

An Int can act like a lot of things

- like an equatable thing,
- like an ordered thing,
- like an enumerable thing, etc.

http://learnyouahaskell.com/functors-applicative-functors-and-monoids

Open Typeclasses

Typeclasses are open:

- can define our own data type,
- can think about what it can act like
- can **connect** it with the typeclasses that define its behaviors.

Act
Behavior
Operation

allows us to know a lot about a **function**
just by knowing its type declaration,
can define typeclasses that define behavior
that's very general and abstract.

Define
Connect

Example:
typeclasses that define operations for seeing if two things are equal
or comparing two things by some ordering.

- those are very **abstract** and elegant behaviors,
- those are not anything very **special**
  because we've been dealing with them for most of our lives.

http://learnyouahaskell.com/functors-applicative-functors-and-monoids

Functors, Applicatives, Monads

functors:	you apply a function to a wrapped value
applicatives:	you apply a wrapped function to a wrapped value
monads:	you apply a function that returns a wrapped value, to a wrapped value

functors:	using **fmap** or **<$>**
applicatives:	using **<*>** or **liftA**
monads:	using **>>=** or **liftM**

https://softwareengineering.stackexchange.com/questions/303472/what-is-the-purpose-of-wrapped-values-in-haskell

Functors

Functors use the **fmap** or **<$>** functions

fmap or **<$>** **Functor f => (a -> b) -> f a -> f b**

This takes a function and applies to to the wrapped elements

```
fmap (\x -> x + 1) (Just 1)      -- Applies (+1) to the inner value, returning (Just 2)
fmap (\x -> x + 1) Nothing       -- Applies (+1) to an empty wrapper, returning Nothing

fmap (\x -> x + 1) [1, 2, 3]     -- Applies (+1) to all inner values, returning [2, 3, 4]
(\x -> x + 1) <$> [1, 2, 3]      -- Same as above
```

https://softwareengineering.stackexchange.com/questions/303472/what-is-the-purpose-of-wrapped-values-in-haskell

Applicatives

Applicatives use the **<*>** function:

<*> Applicative f => f (a -> b) -> f a -> f b

This takes a wrapped function and applies it to the wrapped elements

```
(Just (\x -> x + 1)) <*> (Just 1)        -- Returns (Just 2)
(Just (\x -> x + 1)) <*> Nothing         -- Returns Nothing
Nothing <*> (Just 1)                     -- Returns Nothing
[(*2), (*4)] <*> [1, 2]                  -- Returns [2, 4, 4, 8]
```

https://softwareengineering.stackexchange.com/questions/303472/what-is-the-purpose-of-wrapped-values-in-haskell

Monads – return

There are two relevant functions in the Monad typeclass:

```
return Monad m => a -> m a
(>>=) Monad m => m a -> (a -> m b) -> m b
```

The return function takes a raw, unwrapped value, and wraps it up in the desired monadic type.

```
makeJust :: a -> Maybe a
makeJust x = return x

let foo = makeJust 10          -- returns (Just 10)
```

https://softwareengineering.stackexchange.com/questions/303472/what-is-the-purpose-of-wrapped-values-in-haskell

Monads – bind

The bind function lets you
temporarily unwrap the inner elements of a Monad
and pass them to a function that performs some action
that wraps them back UP in the same monad.

This can be used with the return function in trivial cases:

```
[1, 2, 3, 4] >>= (\x -> return (x + 1))      -- Returns [2, 3, 4, 5]
(Just 1) >>= (\x -> return (x + 1))          -- Returns (Just 2)
Nothing >>= (\x -> return (x + 1))           -- Returns Nothing
```

https://softwareengineering.stackexchange.com/questions/303472/what-is-the-purpose-of-wrapped-values-in-haskell

Monads – a chain of functions

Where it gets interesting is when you have functions to chain together
that don't require you to use return.

```
getLine IO String
putStrLn String -> IO ()
```

You can call these functions like so:

```
getLine >>= (\x -> putStrLn x)      -- Gets a line from IO and prints it to the console
getLine >>= putStrLn                -- With currying, this is the same as above
```

```
-- Reads a line from IO, converts to a number, adds 10 and prints it
getLine >>= (return . read) >>= (return . (+10)) >>= putStrLn . show
```

https://softwareengineering.stackexchange.com/questions/303472/what-is-the-purpose-of-wrapped-values-in-haskell

Promises and Mediators

the concept of **promises** that's been gaining traction recently (particularly in Javascript).

A **promise** is an object that acts as a placeholder
for the result value of an asynchronous, background computation,
like fetching some data from a remote service.

a **mediator** between the asynchronous computation
and functions that need to operate on its anticipated result.

Act
Behavior
Operation

Define
Connect

https://softwareengineering.stackexchange.com/questions/303472/what-is-the-purpose-of-wrapped-values-in-haskell

General Monad - MonadPlus

Haskell's **Control.Monad** module defines a typeclass, **MonadPlus**,
that enables abstract the common pattern eliminating **case** expressions.

```
class Monad m => MonadPlus m where
  mzero :: m a
  mplus :: m a -> m a -> m a
```

class (Monad m) => MonadPlus m where

```
instance MonadPlus [] where
  mzero = []
  Mplus = (++)
```

```
instance MonadPlus Maybe where
  mzero = Nothing

  Nothing `mplus` ys  = ys
  xs      `mplus` _ = xs
```

http://book.realworldhaskell.org/read/programming-with-monads.html

General Monad - MonadPlus Laws

The class **MonadPlus** is used for monads that have a zero element and a plus operation:

```
class (Monad m) => MonadPlus m where
   mzero       :: m a
   mplus       :: m a -> m a -> m a
```

For lists, the zero value is [], the empty list.
The I/O monad has no zero element and
is not a member of this class.

```
m >>= \x -> mzero    =    mzero
mzero >>= m          =    mzero
```

The zero element laws:

```
m `mplus` mplus      =    m
mplus `mplus` m      =    m
```

The laws governing the mplus operator

The mplus operator is ordinary list concatenation in the list monad.

http://book.realworldhaskell.org/read/programming-with-monads.html

Functional Dependency (fundep)

```
class class Mult | a b -> c where
  (*) :: a -> b -> c
```

c is <u>uniquely</u> <u>determined</u> from **a** and **b**

.

Fundeps are not standard Haskell 98.
(Nor are multi-parameter type classes, for that matter.)
They are, however, supported at least in GHC and Hugs
and will almost certainly end up in Haskell'.

```
class class Mult where
  (*) :: a -> b -> c
```

https://wiki.haskell.org/Functional_dependencies

References

[1] ftp://ftp.geoinfo.tuwien.ac.at/navratil/HaskellTutorial.pdf
[2] https://www.umiacs.umd.edu/~hal/docs/daume02yaht.pdf