Applicatives Methods (3B)

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

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The definition of Applicative

```
class (Functor f) => Applicative f where
    pure :: a -> f a
    (<*>) :: f (a -> b) -> f a -> f b
```

The class has a two methods :

pure brings arbitrary values into the functor

(<*>) takes a function wrapped in a functor **f**
and a value wrapped in a functor **f**
and returns the result of the application
which is also wrapped in a functor **f**

https://en.wikibooks.org/wiki/Haskell/Applicative_functors

The Maybe instance of Applicative

```
instance Applicative Maybe where
    pure                    = Just
    (Just f) <*> (Just x)   = Just (f x)
    _        <*> _          = Nothing
```

pure wraps the value with **Just**;

(<*>) applies

the function wrapped in **Just**

to the value wrapped in **Just** if both exist,

and results in **Nothing** otherwise.

https://en.wikibooks.org/wiki/Haskell/Applicative_functors

An Instance of the Applicative Typeclass

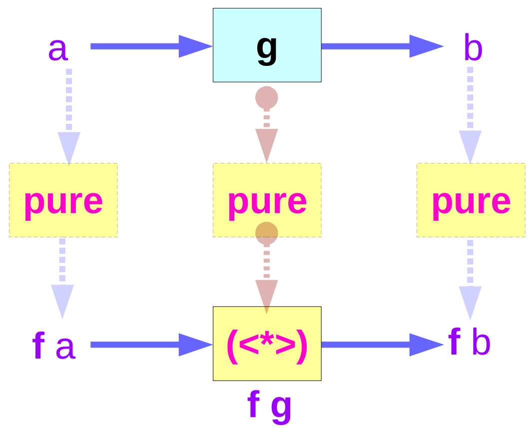
```
class (Functor f) => Applicative f where
    pure :: a -> f a
    (<*>) :: f (a -> b) -> f a -> f b
```

f : Functor, Applicative

(**Functor f**) => **Applicative f**

```
instance Applicative Maybe where
    pure = Just
    Nothing <*> _ = Nothing
    (Just f) <*> something = fmap f something
```

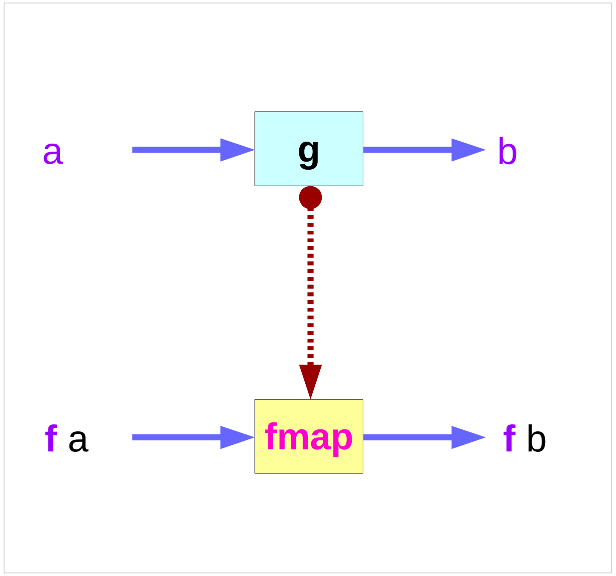
f : function in a context

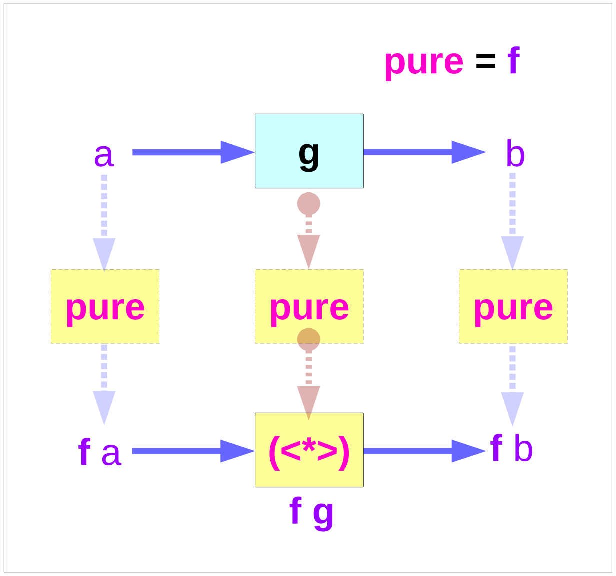


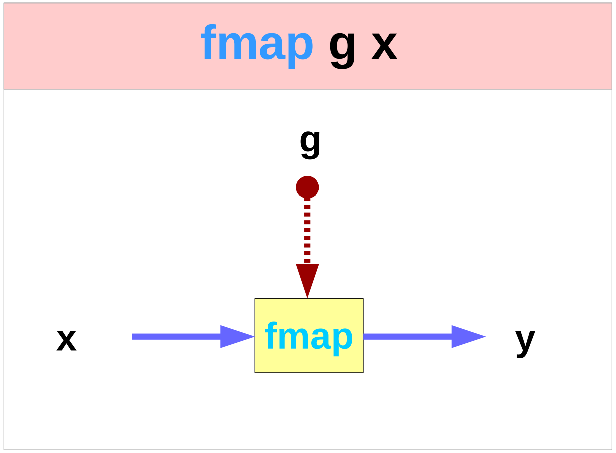
(**Functor f**) => **Applicative f**

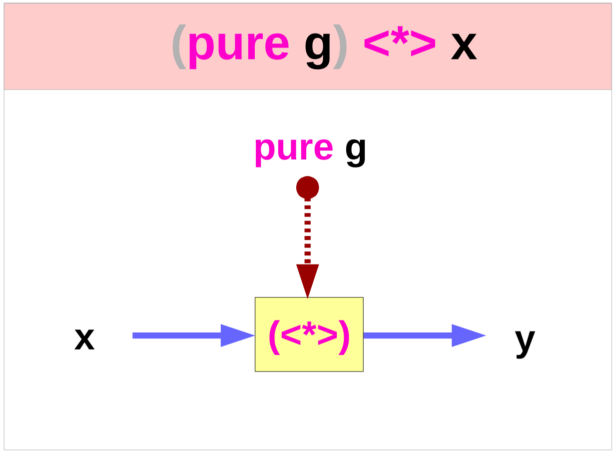
http://learnyouahaskell.com/functors-applicative-functors-and-monoids

fmap g x = (pure g) <*> x









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Left Associative <*>

ghci> **pure** (+) **<*>** **Just** 3 **<*>** **Just** 5

Just 8

pure (+) **<*>** **Just** 3 **<*>** **Just** 5

pure (**+3**) **<*>** **Just** 5

Just 8

ghci> **pure** (+) **<*>** **Just** 3 **<*>** **Nothing**

Nothing

ghci> **pure** (+) **<*>** Nothing **<*>** **Just** 5

Nothing

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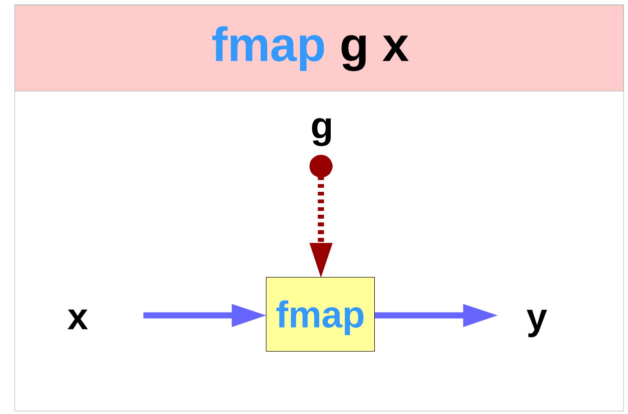
Infix Operator <$>

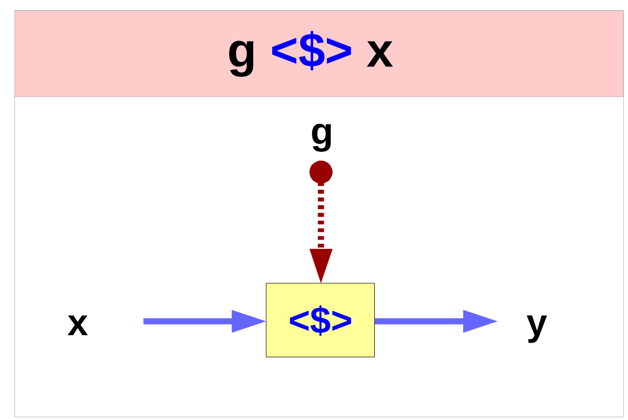
```
pure f <*> x <*> y <*> z
```

```
fmap f x <*> y <*> z
```

Infix operator

```
f <$> x <*> y <*> z
```





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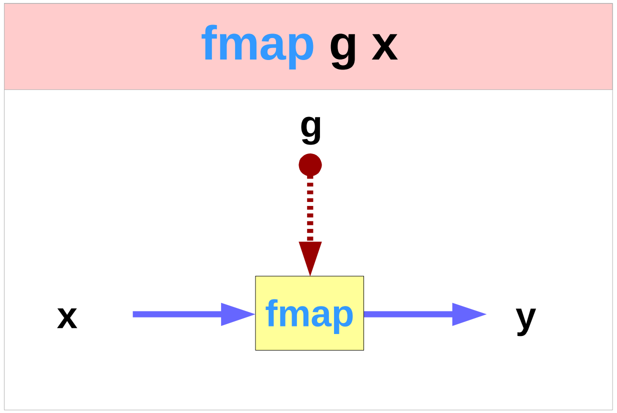
Infix Operator <$> : not a class method

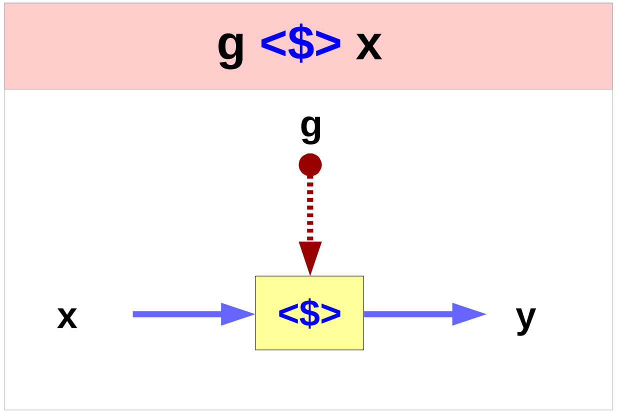
```
class (Functor f) => Applicative f where
    pure :: a -> f a
    (<*>) :: f (a -> b) -> f a -> f b
```

not a class method

```
(<$>) :: (Functor f) => (a -> b) -> f a -> f b
f <$> x = fmap f x
```

```
instance Applicative Maybe where
    pure = Just
    Nothing <*> _ = Nothing
    (Just f) <*> something = fmap f something
```





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The Applicative Typeclass

Applicative is a superclass of **Monad**.

every **Monad** is also a **Functor** and an **Applicative**

fmap, **pure**, **(<*>)** can all be used with **monad**s.

a **Monad** instance also requires

Functor and **Applicative** instances.

the types and roles of **return** and **(>>)**

https://en.wikibooks.org/wiki/Haskell/Applicative_functors

(*> v.s. >>) and (pure v.s. return)

```
(*>) ::     Applicative f  =>  f a ->  f b ->  f b
(>>) ::     Monad m        =>  m a ->  m b ->  m b

pure ::     Applicative f  =>  a ->    f a
return ::   Monad m        =>  a ->    m a
```

the constraint changes from **Applicative** to **Monad**.

(*>) in **Applicative** | **(>>)** in **Monad**

pure in **Applicative** | **return** in **Monad**

https://en.wikibooks.org/wiki/Haskell/Applicative_functors

The Applicative Laws

The identity law: `pure id <*> v = v`

Homomorphism: `pure f <*> pure x = pure (f x)`

Interchange: `u <*> pure y = pure ($ y) <*> u`

Composition: `u <*> (v <*> w) = pure (.) <*> u <*> v <*> w`

The Identity Law

The identity law	**pure id <*> v = v**

pure to inject values into the functor

in a default, featureless way,

so that the result is as close as possible to the plain value.

applying the **pure id** morphism does nothing,

exactly like with the plain **id** function.

https://en.wikibooks.org/wiki/Haskell/Applicative_functors

The Homomorphism Law

The homomorphism law	**pure f <*> pure x = pure (f x)**

applying a "**pure**" function to a "**pure**" value is the same as
applying the function to the value in the normal way
and then using **pure** on the result.
means **pure** preserves function application.

applying a non-effectful function **f**
to a non-effectful argument **x** in an effectful context **pure**
is the same as just **applying** the function **f** to the argument **x**
and then injecting the result **(f x)** into the context with **pure**.

https://en.wikibooks.org/wiki/Haskell/Applicative_functors

The Interchange Law

The interchange law **u <*> pure y = pure ($ y) <*> u**

applying a morphism **u** to a "**pure**" value **pure y**

is the same as applying **pure** (**$ y**) to the morphism **u**

(**$ y**) is the function that supplies **y** as argument to another function

– the higher order functions

when evaluating the application of

an effectful function **u** to a pure argument **pure y**,

the order in which we evaluate

the function **u** and its argument **pure y** doesn't matter.

https://en.wikibooks.org/wiki/Haskell/Applicative_functors

The Composition Law

The composition law `pure (.) <*> u <*> v <*> w = u <*> (v <*> w)`

pure (.) composes morphisms similarly
to how **(.)** composes functions:

`(f . g)  x  = f (g x)`

`pure (.) <*> pure f <*> pure g <*> pure x`
`= pure f <*> (pure g <*> pure x)`

`u = pure f`
`v = pure g`
`w = pure x`

applying the composed morphism `pure (.) <*> u <*> v` to **w**
gives the same result as applying **u** — `u`
to the result of applying **v** to **w** — `(v <*> w)`

it is expressing a sort of associativity property of (`<*>`).

https://en.wikibooks.org/wiki/Haskell/Applicative_functors

<$> related operators

Functor map <$>

(<$>) :: Functor f => (a -> b) -> f a -> f b

(<$) :: Functor f => a -> f b -> f a

($>) :: Functor f => f a -> b -> f b

The **<$>** operator is just a synonym
for the **fmap** function from the Functor typeclass.

This function generalizes the **map** function for lists
to many other data types, such as **Maybe**, **IO**, and **Map**.

https://haskell-lang.org/tutorial/operators

<$> exammples

```
#!/usr/bin/env stack
-- stack --resolver ghc-7.10.3 runghc
import Data.Monoid ((<>))

main :: IO ()
main = do
   putStrLn "Enter your year of birth"
   year <- read <$> getLine
   let age :: Int
       age = 2020 - year
   putStrLn $ "Age in 2020: " <> show age
```

https://haskell-lang.org/tutorial/operators

<$**, **$> operators

In addition, there are two additional operators provided
which replace a value inside a Functor
instead of applying a function.
This can be both more convenient in some cases,
as well as for some Functors be more efficient.

value <$ functor = const value <$> functor

functor $> value = const value <$> functor

x <$ y = y $> x

x $> y = y <$ x

https://haskell-lang.org/tutorial/operators

<*> related operators

Applicative function application <*>

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

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

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

Commonly seen with **<$>**, **<*>** is an operator
that applies a wrapped function to a wrapped value.
It is part of the Applicative typeclass,
and is very often seen in code like the following:

foo <$> bar <*> baz

https://haskell-lang.org/tutorial/operators

<*> examples

For cases when you're dealing with a Monad, this is equivalent to:

```
do x <- bar
   y <- baz
   return (foo x y)
```

Other common examples including parsers and serialization libraries.

Here's an example you might see using the aeson package:

```
data Person = Person { name :: Text, age :: Int } deriving Show

-- We expect a JSON object, so we fail at any non-Object value.
instance FromJSON Person where
    parseJSON (Object v) = Person <$> v .: "name" <*> v .: "age"
    parseJSON _ = empty
```

https://haskell-lang.org/tutorial/operators

*> operator

To go along with this, we have two helper operators that are less frequently used:

***>** ignores the value from the first argument. It can be defined as:

```
a1 *> a2 = (id <$ a1) <*> a2
```

Or in do-notation:

```
a1 *> a2 = do
  _ <- a1
  a2
```

For Monads, this is completely equivalent to **>>**.

https://haskell-lang.org/tutorial/operators

<* operator

<* is the same thing in reverse: perform the first action then the second,

but only take the value from the first action.

Again, definitions in terms of **<*>** and do-notation:

```
(<*) = liftA2 const
```

```
a1 <* a2 = do
    res <- a1
    _ <- a2
    return res
```

https://haskell-lang.org/tutorial/operators

liftA2

liftA2 :: (a -> b -> c) -> f a -> f b -> f c

Lift a binary function to actions.

Some functors support an implementation of liftA2
that is more efficient than the default one.

In particular, if fmap is an expensive operation,
it is likely better to use liftA2
than to fmap over the structure and then use <*>.

http://hackage.haskell.org/package/base-4.10.1.0/docs/Control-Applicative.html#v:liftA2

liftA2

If you have the variables

f :: a -> b -> c

a :: f a

b :: f b

you can combine them in the following ways with the same result of type f c

:

```
pure f <*> a <*> b
liftA2 f a b
```

But how to cope with let

and sharing in the presence of effects?

https://wiki.haskell.org/Applicative_functor

liftA2

Consider the non-functorial expression:

x :: x
g :: x -> y
h :: y -> y -> z

let y = g x
in h y y

Very simple. Now we like to generalize this to

fx :: f x
fg :: f (x -> y)
fh :: f (y -> y -> z)

https://wiki.haskell.org/Applicative_functor

liftA2

However, we note that

let fy = fg <*> fx

in fh <*> fy <*> fy

runs the effect of fy

twice. E.g. if fy

writes something to the terminal then fh <*> fy <*> fy

writes twice. This could be intended, but how can we achieve, that the effect is run only once and the result is used twice? Actually, using the liftA

commands we can pull results of applicative functors into a scope where we can talk exclusively about functor results and not about effects. Note that functor results can also be functions. This scope is simply a function, which contains the code that we used in the non-functorial setting.

```
liftA3
   (\x g h -> let y = g x in h y y)
   fx fg fh
```

The order of effects is entirely determined by the order of arguments to liftA3

.

https://wiki.haskell.org/Applicative_functor

References

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