



Applicatives

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Agenda



- ▶ Recap of Functors
- ▶ Applicative



```
class Functor f where
  fmap :: (a -> b) -> f a -> f b
  (<$) :: a -> f b -> f a
```

Functors Laws

- ▶ Must preserve identity

```
fmap id = id
```

- ▶ Must preserve composition of morphism

```
fmap (f . g) == fmap f . fmap g
```

¹Category Design Pattern

²Functor Design Pattern



- ▶ For something to be a functor, it has to be a first order kind.



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

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

fmap f x = pure f <*> x
```

Examples



```
pure (+1) <*> [1..3]  
[2, 3, 4]
```

```
[(*2), (*3)] <*> [4, 5]  
[8, 10, 12, 15]
```

```
("Woo", (+1)) <*> (" Hoo!", 0)  
("Woo Hoo!", 1)
```

```
(Sum 2, (+1)) <*> (Sum 0, 0)  
(Sum {getSum = 2}, 1)
```

```
(Product 3, (+9)) <*> (Product 2, 8)  
(Product {getProduct = 6}, 17)
```

```
(,) <$> [1, 2] <*> [3, 4]  
[(1, 3), (1, 4), (2, 3), (2, 4)]
```



Person

```
<$> parseString "name" o  
<*> parseInt "age" o  
<*> parseTelephone "telephone" o
```

Can also be written as

```
liftA3 Person  
  (parseString "name" o)  
  (parseInt "age" o)  
  (parseTelephone "telephone" o)
```

⁴FP Complete - Crash course to Applicative syntax



```
parsePerson :: Parser Person
parsePerson = do
  string "Name: "
  name <- takeWhile (/= 'n')
  endOfLine
  string "Age: "
  age <- decimal
  endOfLine
  pure $ Person name age
```

⁵FP Complete - Crash course to Applicative syntax



```
helper :: () -> Text -> () -> () -> Int -> () -> Person
helper () name () () age () = Person name age
```

```
parsePerson :: Parser Person
```

```
parsePerson = helper
  <$> string "Name: "
  <*> takeWhile (/= 'n')
  <*> endOfLine
  <*> string "Age: "
  <*> decimal
  <*> endOfLine
```

⁶FP Complete - Crash course to Applicative syntax



- ▶ Seeing Functor as unary lifting and Applicative as n-ary lifting

```
liftA0 :: Applicative f => (a)           -> (f a)
liftA1 :: Functor      f => (a -> b)     -> (f a -> f b)
liftA2 :: Applicative f => (a -> b -> c)  -> (f a -> f b -> f c)
liftA3 :: Applicative f => (a -> b -> c -> d) -> (f a -> f b -> f c -> f d)
liftA4 :: Applicative f => ..
```

Where `liftA0 = pure` and `liftA1 = fmap`.

Monoidal functors



- ▶ Remember Monoid?

```
class Monoid m where
```

```
  mempty :: m
```

```
  mappend :: m -> m -> m
```

```
($)    :: (a -> b) -> a -> b
```

```
(<$>)  :: (a -> b) -> f a -> f b
```

```
(<*>) :: f (a -> b) -> f a -> f b
```

```
mappend ::      f          f          f
```

```
($) ::      (a -> b) -> a -> b
```

```
<*> ::      f (a -> b) -> f a -> f b
```

```
instance Monoid a => Applicative ((,) a) where
```

```
  pure x = (mempty, x)
```

```
  (u, f) <*> (v, x) = (u `mappend` v, f x)
```

Where are monoids again



```
fmap (+1) ("blah", 0)  
("blah", 1)
```

```
("Woo", (+1)) <*> (" Hoo!", 0)  
("Woo Hoo!", 1)
```

```
(,) <$> [1, 2] <*> [3, 4]  
[(1,3), (1,4), (2,3), (2,4)]
```

```
liftA2 (,) [1, 2] [3, 4]  
[(1,3), (1,4), (2,3), (2,4)]
```



► Applying a function to an effectful argument

`(<$>)` :: **Functor** m => (a -> b) -> m a -> m b

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

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



- ▶ No data dependency between $f\ a$ and $f\ b$
- ▶ Result of $f\ a$ can't possibly influence the behaviour of $f\ b$
- ▶ That needs something like $a \rightarrow f\ b$

Applicative laws



-- Identity

`pure id <*> v = v`

-- Composition

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

-- Homomorphism

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

-- Interchange

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



- ▶ `pure` wraps up a pure value into some kind of `Applicative`
- ▶ `liftA2` applies a pure function to the values inside two `Applicative` wrapped values
- ▶ `<$>` operator version of `fmap`
- ▶ `<*>` apply a wrapped function to a wrapped value
- ▶ `*>`, `<*`



- ▶ Applicative
 - ▶ Effects
 - ▶ Batching and aggregation
 - ▶ Concurrency/Independent
 - ▶ Parsing context free grammar
 - ▶ Exploring all branches of computation (see **Alternative**)
- ▶ Monads
 - ▶ Effects
 - ▶ Composition
 - ▶ Sequence/Dependent
 - ▶ Parsing context sensitive grammar
 - ▶ Branching on previous results

Weaker but better



- ▶ Weaker than monads but thus also more common
- ▶ Lends itself to optimisation (See Facebook's **Haxl** project)
- ▶ Always opt for the least powerful mechanism to get things done
- ▶ No dependency issues or branching? just use applicative



- ▶ [Applicative Programming with Effects](#)
- ▶ [optparse-applicative](#)
- ▶ [Control Applicative](#)
- ▶ [Applicative functors for fun & parsing](#)



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