Programare funcțională

Introducere în programarea funcțională folosind Haskell

C11

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Functori - recap

Clasa de tipuri Functor

Definiție

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

Dată fiind o funcție f :: a -> b și ca :: f a, fmap produce cb :: f b obținută prin transformarea rezultatelor produse de computația ca folosind funcția f (și doar atât!)

Instanță pentru liste

```
instance Functor [] where
  fmap = map
```

Clasa de tipuri Functor

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

Instanță pentru tipul optiune

fmap :: (a -> b) -> Maybe a -> Maybe b

```
instance Functor Maybe where
  fmap f Nothing = Nothing
  fmap f (Just x) = Just (f x)
```

Proprietăți ale functorilor

- Argumentul f al lui Functor f definește o transformare de tipuri
  - f a este tipul a transformat prin functorul f
- fmap definește transformarea corespunzătoare a funcțiilor
  - fmap :: (a -> b) -> (f a -> f b)

Contractul lui fmap

- fmap f ca e obținută prin transformarea rezultatelor produse de computația ca folosind funcția f (și doar atât!)
- Abstractizat prin două legi:

  identitate fmap **id** == **id**

  compunere fmap (g . h) == fmap g . fmap h

Functori aplicativi

Problemă

- Folosind fmap putem transforma o funcție h :: a –> b într-o funcție între colecții/computații fmap h :: m a –> m b
- Dar ce se întâmplă dacă avem o funcție cu mai multe argumente?
  E.g., cum trecem de la h :: a –> b –> c la
  h' :: m a –> m b –> m c
- putem încerca să folosim fmap

Problemă

- Folosind fmap putem transforma o funcție h :: a –> b într-o funcție între colecții/computații fmap h :: m a –> m b
- Dar ce se întâmplă dacă avem o funcție cu mai multe argumente?
  E.g., cum trecem de la h :: a –> b –> c la
  h' :: m a –> m b –> m c
- putem încerca să folosim fmap
- Dar, deoarece h :: a –> (b –> c), avem că
  fmap h :: m a –> m (b –> c)
- Putem aplica fmap h la o valoare ca :: m a și obținem
  fmap h ca :: m (b –> c)

Problemă

Cum transformăm un obiect din m (b –> c) într-o funcție m b –> m c?

- **ap** :: m (b –> c) –> (m b –> m c), sau, ca operator
- (<*>) :: m (b –> c) –> m b –> m c

Merge pentru funcții cu oricâte argumente

Problemă

Dată fiind o funcție

f :: a1 –> a2 –> a3 –> ... –> an –> a

și computațiile

ca1 :: m a1, ca2 :: m a2, . . . , can :: m an,

vrem să „aplicăm” funcția *f* pe rând computațiilor ca1, . . . , can pentru a obține o computație finală ca :: m a.

Merge pentru funcții cu oricâte argumente

Date fiind

- f :: a1 –> a2 –> a3 –> ... –> an –> a
- ca1 :: m a1, ca2 :: m a2, . . . , can :: m an,
- fmap :: (a –> b) –> m a –> m b
- (<*>) :: m (b –> c) –> m b –> m c cu „proprietăți bune”

Merge pentru funcții cu oricâte argumente

Date fiind

- f :: a1 –> a2 –> a3 –> ... –> an –> a
- ca1 :: m a1, ca2 :: m a2, . . . , can :: m an,
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- (<*>) :: m (b –> c) –> m b –> m c cu „proprietăți bune”

Atunci

fmap f :: m a1 –> m (a2 –> a3 –> ... –> an –> a)

Merge pentru funcții cu oricâte argumente

Date fiind

- f :: a1 –> a2 –> a3 –> ... –> an –> a
- ca1 :: m a1, ca2 :: m a2, . . . , can :: m an,
- fmap :: (a –> b) –> m a –> m b
- (<*>) :: m (b –> c) –> m b –> m c cu „proprietăți bune”

Atunci

fmap f :: m a1 –> m (a2 –> a3 –> ... –> an –> a)

fmap f ca1 :: m (a2 –> a3 –> ... –> an –> a)

Merge pentru funcții cu oricâte argumente

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- f :: a1 –> a2 –> a3 –> ... –> an –> a
- ca1 :: m a1, ca2 :: m a2, . . . , can :: m an,
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- (<*>) :: m (b –> c) –> m b –> m c cu „proprietăți bune”

Atunci

fmap f :: m a1 –> m (a2 –> a3 –> ... –> an –> a)

fmap f ca1 :: m (a2 –> a3 –> ... –> an –> a)

fmap f ca1 <*> ca2 :: m (a3 –> ... –> an –> a)

Merge pentru funcții cu oricâte argumente

Date fiind

- f :: a1 –> a2 –> a3 –> ... –> an –> a
- ca1 :: m a1, ca2 :: m a2, . . . , can :: m an,
- fmap :: (a –> b) –> m a –> m b
- (<*>) :: m (b –> c) –> m b –> m c cu „proprietăți bune”

Atunci

fmap f :: m a1 –> m (a2 –> a3 –> ... –> an –> a)

fmap f ca1 :: m (a2 –> a3 –> ... –> an –> a)

fmap f ca1 <*> ca2 :: m (a3 –> ... –> an –> a)

. . .

fmap f ca1 <*> ca2 <*> ca3 ... <*> can :: m a

Clasa de tipuri Applicative

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

Clasa de tipuri Applicative

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

- Orice instanță a lui Applicative trebuie să fie instanță a lui **Functor**
- pure transformă o valoare într-o computație minimală care are acea valoare ca rezultat, și nimic mai mult!
- (<*>) ia o computație care produce funcții și o computație care produce argumente pentru funcții și obține o computație care produce rezultatele aplicării funcțiilor asupra argumentelor

Clasa de tipuri Applicative

```
class Functor m where
  fmap :: (a -> b) -> m a -> m b

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

Proprietate importantă

- fmap f x == pure f <*> x
- Se definește operatorul (<$>) prin (<$>) = fmap

Instante – Maybe

```haskell
class Functor m where
  fmap :: (a -> b) -> m a -> m b

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


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

Instante – Maybe

```
Prelude> pure "Hey" :: Maybe String
Just "Hey"
```

Instante – Maybe

```
Prelude> pure "Hey" :: Maybe String
Just "Hey"

Prelude> (++) <$> (Just "Hey ") <*> (Just "You!")
Just "Hey You!"
```

Instante – Maybe

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Prelude> pure "Hey" :: Maybe String
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Prelude> (++) <$> (Just "Hey ") <*> (Just "You!")
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```

- (++) :: **String** –> (**String** –> **String**)

Instante – Maybe

```
Prelude> pure "Hey" :: Maybe String
Just "Hey"

Prelude> (++) <$> (Just "Hey ") <*> (Just "You!")
Just "Hey You!"
```

- (++) :: **String** –> (**String** –> **String**)
- **Just** "Hey␣" :: **Maybe String**
- (<$>) :: (a –> b) –> m a –> m b (este fmap)

Instante – Maybe

```
Prelude> pure "Hey" :: Maybe String
Just "Hey"

Prelude> (++) <$> (Just "Hey ") <*> (Just "You!")
Just "Hey You!"
```

- (++) :: **String** –> (**String** –> **String**)
- **Just** "Hey␣" :: **Maybe String**
- (<$>) :: (a –> b) –> m a –> m b (este fmap)
- (++) <$> (**Just** "Hey␣") :: **Maybe** (**String** –> **String**)

Instante – Maybe

```
Prelude> pure "Hey" :: Maybe String
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- (++) :: **String** –> (**String** –> **String**)
- **Just** "Hey␣" :: **Maybe String**
- (<$>) :: (a –> b) –> m a –> m b (este fmap)
- (++) <$> (**Just** "Hey␣") :: **Maybe** (**String** –> **String**)
- **Just** "You!" :: **Maybe String**
- (<*>) :: m (b –> c) –> m b –> m c

Instante – Maybe

```
Prelude> pure "Hey" :: Maybe String
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- (<$>) :: (a –> b) –> m a –> m b (este fmap)
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- **Just** "You!" :: **Maybe String**
- (<*>) :: m (b –> c) –> m b –> m c
- **Just** "Hey␣You!" :: **Maybe String**

Instante – Maybe

```
mDiv x y = if y == 0 then Nothing
           else Just (x `div` y)
mF x = (+) <$> pure 4 <*> mDiv 10 x
```

Instante – Maybe

```
mDiv x y = if y == 0 then Nothing
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- `(+) :: Int -> Int -> Int`

Instante – Maybe

```
mDiv x y = if y == 0 then Nothing
           else Just (x `div` y)
mF x = (+) <$> pure 4 <*> mDiv 10 x
```

- (+) :: **Int** –> **Int** –> **Int**
- pure 4 :: **Maybe Int**
- (<$>) :: (a –> b) –> m a –> m b (este fmap)

Instante – Maybe

```
mDiv x y = if y == 0 then Nothing
           else Just (x `div` y)
mF x = (+) <$> pure 4 <*> mDiv 10 x
```

- (+) :: **Int** –> **Int** –> **Int**
- pure 4 :: **Maybe Int**
- (<$>) :: (a –> b) –> m a –> m b (este fmap)
- (+) <$> pure 4 :: **Maybe** (**Int** –> **Int**)

Instante – Maybe

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mDiv x y = if y == 0 then Nothing
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- (+) :: **Int** –> **Int** –> **Int**
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- mDiv :: **Int** –> **Int** –> **Maybe Int**
- mDiv 10 x :: **Maybe Int**
- (<*>) :: m (b –> c) –> m b –> m c

Instante – Maybe

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mDiv x y = if y == 0 then Nothing
           else Just (x `div` y)
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```

- (+) :: **Int** -> **Int** -> **Int**
- pure 4 :: **Maybe Int**
- (<$>) :: (a -> b) -> m a -> m b (este fmap)
- (+) <$> pure 4 :: **Maybe** (**Int** -> **Int**)
- mDiv :: **Int** -> **Int** -> **Maybe Int**
- mDiv 10 x :: **Maybe Int**
- (<*>) :: m (b -> c) -> m b -> m c

```
Prelude> mF 2
Just 9
```

Instante – Maybe

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mDiv x y = if y == 0 then Nothing
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- (+) :: **Int** –> **Int** –> **Int**
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```
Prelude> mF 2
Just 9
Prelude> let f x = 4 + 10 `div` x
Prelude> fmap f (Just 2)
Just 9
```

Instante – Either

```haskell
class Functor m where
  fmap :: (a -> b) -> m a -> m b

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


instance Applicative (Either a) where
  pure = Right
  Left e  <*> _ = Left e
  Right f <*> x = fmap f x
```

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Prelude> pure "Hey" :: Either a String
Right "Hey"
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Instante – Either

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- (++) :: **String** –> (**String** –> **String**)
- **Right** "Hey␣" :: **Either** a **String**
- (<$>) :: (a –> b) –> m a –> m b (este fmap)

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- (<*>) :: m (b –> c) –> m b –> m c

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- (++) :: **String** –> (**String** –> **String**)
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- **Right** "You!" :: **Either** a **String**
- (<*>) :: m (b –> c) –> m b –> m c
- **Right** "Hey␣You!" :: **Either** a **String**

Instante – Either

```
eDiv x y = if y == 0 then Left "Division by 0!"
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eF x = (+) <$> pure 4 <*> eDiv 10 x
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Instante – Either

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eDiv x y = if y == 0 then Left "Division by 0!"
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```

- `(+) :: Int -> Int -> Int`

Instante – Either

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eDiv x y = if y == 0 then Left "Division by 0!"
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- (+) :: **Int** –> **Int** –> **Int**
- pure 4 :: **Either String Int**
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- (+) <$> pure 4 :: **Either String** (**Int** –> **Int**)

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Prelude> eF 2
Right 9
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```
Prelude> eF 2
Right 9
Prelude> let f x = 4 + 10 `div` x
Prelude> fmap f (Right 2)
Right 9
```

Instante – Liste

```haskell
class Functor m where
  fmap :: (a -> b) -> m a -> m b

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


instance Applicative [] where
  pure x = [x]
  fs <*> xs = [f x | f <- fs, x <- xs]
```

Instante – Liste

```
Prelude> pure "Hey" :: [String]
["Hey"]
```

Instante – Liste

```
Prelude> pure "Hey" :: [String]
["Hey"]

Prelude> (++) <$> ["Hello ", "Goodbye "] <*> ["world"
    , "happiness"]
["Hello world","Hello happiness","Goodbye world","
    Goodbye happiness"]
```

Instante – Liste

```
Prelude> pure "Hey" :: [String]
["Hey"]

Prelude> (++) <$> ["Hello ", "Goodbye "] <*> ["world"
    , "happiness"]
["Hello world","Hello happiness","Goodbye world","
   Goodbye happiness"]
```

- (++) :: **String** –> (**String** –> **String**)

Instante – Liste

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["Hello world","Hello happiness","Goodbye world","
   Goodbye happiness"]
```

- (++) :: **String** –> (**String** –> **String**)
- ["Hello␣", "Goodbye␣"] :: [**String**]
- (<$>) :: (a –> b) –> m a –> m b (este fmap)

Instante – Liste

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Prelude> pure "Hey" :: [String]
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- (++) :: **String** –> (**String** –> **String**)
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- ["Hello␣", "Goodbye␣"] :: [**String**]
- (<$>) :: (a –> b) –> m a –> m b (este fmap)
- (++) <$> ["Hello␣", "Goodbye␣"] :: [**String** –> **String**]
- ["world", "happiness"] :: [**String**]
- (<*>) :: m (b –> c) –> m b –> m c

Instante – Liste

```
Prelude> [(+),(*)] <*> [1,2] <*> [3,4]
[4,5,5,6,3,4,6,8]
```

Instante – Liste

```
Prelude> [(+),(*)] <*> [1,2] <*> [3,4]
[4,5,5,6,3,4,6,8]
```

- `(+),(*) :: Int -> Int -> Int`
- `[(+),(*)] :: [Int -> Int -> Int]`

Instante – Liste

```
Prelude> [(+),(*)] <*> [1,2] <*> [3,4]
[4,5,5,6,3,4,6,8]
```

- (+),(*) :: **Int** –> **Int** –> **Int**
- [(+),(*)] :: [**Int** –> **Int** –> **Int**]
- [1,2] :: [**Int**]
- (<*>) :: m (b –> c) –> m b –> m c
- [(+),(*)] <*> [1,2] :: [**Int** –> **Int**]

Instante – Liste

```
Prelude> [(+),(*)] <*> [1,2] <*> [3,4]
[4,5,5,6,3,4,6,8]
```

- `(+),(*)` :: **Int** –> **Int** –> **Int**
- `[(+),(*)]` :: [**Int** –> **Int** –> **Int**]
- `[1,2]` :: [**Int**]
- `(<*>)` :: m (b –> c) –> m b –> m c
- `[(+),(*)] <*> [1,2]` :: [**Int** –> **Int**]
- `[(+),(*)] <*> [1,2] <*> [3,4]` :: [**Int**]

Instante – Liste

```
Prelude> filter (>50) $ (*) <$> [2,5,10] <*> [8,10,11]
[55,80,100,110]
```

Instante – Liste

```
Prelude> filter (>50) $ (*) <$> [2,5,10] <*> [8,10,11]
[55,80,100,110]
```

- (*) :: **Int** -> **Int** -> **Int**
- [2,5,10] :: [**Int**]
- (<$>) :: (a -> b) -> m a -> m b (este fmap)

Instante – Liste

```
Prelude> filter (>50) $ (*) <$> [2,5,10] <*> [8,10,11]
[55,80,100,110]
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- (*) :: **Int** -> **Int** -> **Int**
- [2,5,10] :: [**Int**]
- (<$>) :: (a -> b) -> m a -> m b (este fmap)
- (*) <$> [2,5,10] :: [**Int** -> **Int**]

Instante – Liste

```
Prelude> filter (>50) $ (*) <$> [2,5,10] <*> [8,10,11]
[55,80,100,110]
```

- (*) :: **Int** -> **Int** -> **Int**
- [2,5,10] :: [**Int**]
- (<$>) :: (a -> b) -> m a -> m b (este fmap)
- (*) <$> [2,5,10] :: [**Int** -> **Int**]
- (<*>) :: m (b -> c) -> m b -> m c
- (*) <$> [2,5,10] <*> [8,10,11] :: [**Int**]

Instante – Liste

```
Prelude> filter (>50) $ (*) <$> [2,5,10] <*> [8,10,11]
[55,80,100,110]
```

- (*) :: **Int** -> **Int** -> **Int**
- [2,5,10] :: [**Int**]
- (<$>) :: (a -> b) -> m a -> m b (este fmap)
- (*) <$> [2,5,10] :: [**Int** -> **Int**]
- (<*>) :: m (b -> c) -> m b -> m c
- (*) <$> [2,5,10] <*> [8,10,11] :: [**Int**]

```
Prelude> (*) <$> [2,5,10] <*> [8,10,11]
[16,20,22,40,50,55,80,100,110]
```

Proprietăți ale functorilor aplicativi

```
class Functor m where
  fmap :: (a -> b) -> m a -> m b

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

- identitate pure **id** <*> v = v
- compoziție pure (.) <*> u <*> v <*> w = u <*> (v <*> w)
- homomorfism pure f <*> pure x = pure (f x)

Consecință: fmap f x == f <$> x == pure f <*> x

Functori aplicativi

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

Quiz time!

Seria 23: https://www.questionpro.com/t/AT4qgZqjts

Seria 24: https://www.questionpro.com/t/AT4NiZqjWQ

Seria 25: https://www.questionpro.com/t/AT4qgZqjt3

Pe săptămâna viitoare!