

Functional Programming

Test data generators

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An application of type classes and monads

Remember QuickCheck for testing

- Automatic generation of test cases to test properties specified by the programmer
- So far restricted to properties on predefined types

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Test data can be generated for the instances of a type class `Arbitrary` (defined by QuickCheck)

To extend the scope of QuickCheck...

- we only need to write new instance of `Arbitrary`!
- (require the IO monad)

An example

```
prop_binomi :: Integer -> Integer -> Bool
prop_binomi a b = (a + b) ^ 2 == a ^ 2 + 2 * a * b + b ^ 2
```

can be checked

```
Main> quickCheck prop_binomi
+++ OK, passed 100 tests.
```

Arbitrary and Gen

Type class Arbitrary

```
class Arbitrary a where
```

```
  arbitrary :: Gen a -- generate values of type a
```

```
  shrink :: a -> [a] -- shrink values of type a
```

Type Gen a: instructions for creating a random value of type a (a monad)

Arbitrary and Gen

Type class Arbitrary

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class Arbitrary a where
  arbitrary :: Gen a -- generate values of type a
  shrink    :: a -> [a] -- shrink values of type a
```

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Functions for sampling a random generator

```
sample    :: Show a => Gen a -> IO ()
sample'   :: Gen a -> IO [a]
generate  :: Gen a -> IO a
```

Sampling test data

Remember `sample' :: Gen a -> IO [a]`

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- `[0,2,0,6,5,2,-12,9,-15,-2,20]`

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- `Main> sample' (arbitrary :: Gen Int)`
- `[0,-1,0,5,3,-1,-11,-8,14,-10,-19]`

Building generators

```
elements  :: [a] -> Gen a
oneof     :: [Gen a] -> Gen a
frequency :: [(Int, Gen a)] -> Gen a
listOf    :: Gen a -> Gen [a]
vectorOf  :: Int -> Gen a -> Gen [a]
choose    :: Random a => (a,a) -> Gen a
```

- Random is a predefined class for generating random data
- (some experiments)

Generating a Suit

```
data Suit = Spades | Hearts | Diamonds | Clubs  
  deriving (Show, Eq)
```

Generating a Rank

```
data Rank = Numeric Integer | Jack | Queen  
          | King | Ace  
          deriving (Show, Eq, Ord)
```

Generating a card

```
data Card = Card { rank :: Rank, suit :: Suit }  
    deriving (Show)
```

- need to combine a generator for Rank and one for Suit
- no provision in the QuickCheck library, but ...

Gen is a monad

- `Gen a` is the type of instructions to generate random values of type `a`
- `IO a` is the type of instructions for IO operations with result `a`
- Both are monads \Rightarrow use `bind >>=` to combine generators
- Alternatively, the `do` notation can be used with `Gen`

Examples

Generate

- Card
- constant, twice
- even integers, non-negative integers
- Hand

Task: Check the generator

- `Rank` contains useless values
- does its generator `rRank` only yield useful values?

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Test it!

```
validRank :: Rank -> Bool
validRank (Numeric n) = 2 <= n && n <= 10
validRank _ = True

prop_all_validRank = forAll rRank validRank
```

Checking properties of test data

```
prop_all_valid_rank_collect r = collect r (validRank r)
```

- `collect x` does not change the test
- collects values of `x` and creates a histogram

Task

- Define a property that yields a histogram of generated Hands

Testing properties of `insert`

Testing properties of `insert`

Example

- `insert x xs` inserts a value `x` in an ordered list `xs`
- the output should be ordered again (along with other properties)
- how do we test that?

First attempt

```
prop_insert_1 :: Integer -> [Integer] -> Bool  
prop_insert_1 x xs = isOrdered (insert x xs)
```

Second attempt

```
prop_insert_2 :: Integer -> [Integer] -> Property
prop_insert_2 x xs = isOrdered xs ==> isOrdered (insert x xs)
```

Third attempt

A dedicated generator for sorted lists

```
orderedList :: (Arbitrary a, Ord a) => Gen [a]
```

(How would you implement this generator?)

Third attempt

A dedicated generator for sorted lists

```
orderedList :: (Arbitrary a, Ord a) => Gen [a]
```

(How would you implement this generator?)

Usage

```
prop_insert_3 x =  
  forAll orderedList (\xs->isOrdered (insert x xs))
```

Fourth attempt

A dedicated generator for sorted lists (defined by QuickCheck)

```
data OrderedList a = Ordered [a]

instance (Ord a, Arbitrary a)
    => Arbitrary (OrderedList a) where
    arbitrary = orderedList >>= (return . Ordered)
```


Fourth attempt

A dedicated generator for sorted lists (defined by QuickCheck)

```
data OrderedList a = Ordered [a]

instance (Ord a, Arbitrary a)
    => Arbitrary (OrderedList a) where
    arbitrary = orderedList >=> (return . Ordered)
```

Usage

```
prop_insert_4 x (Ordered xs) = isOrdered (insert x xs)
```

Roll your own test data generators

- populate the class `Arbitrary` with the types you want to generate
- generating managed by monad `Gen`
- conditional test generation