An Introduction to Functional Programming

Glenn R. Fisher

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- **Expressions (Not Instructions)**: Functions compute results instead of performing actions.

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What is Functional Programming?

Functional programming is a different way to think about writing programs.

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- **Expressions (Not Instructions)**: Functions compute results instead of performing actions.
- **Comprehensive Type System**: Create types and catch errors at compile time.

During this talk, we'll try to develop **intuition** behind these ideas.

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Why Learn Functional Programming?

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- Programs are easier to **understand**.
- Shorter, cleaner, and more **maintainable** code.
- Fewer errors. Higher **reliability**.

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Why Learn Functional Programming?

What are the benefits of thinking and programming functionally?

- Programs are easier to **understand**.
- Shorter, cleaner, and more **maintainable** code.
- Fewer errors. Higher **reliability**.
- Excellent **performance** with easy parallelism and concurrency.

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Where is Functional Programming Used?

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Where is Functional Programming Used?

Companies Using Functional Languages:

- Twitter
- Jane Street Capital
- Airbnb
- Intel
- LinkedIn
- Foursquare
- AT&T
- Bank of America
- NVIDIA
- And Many More...

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You don't need to use a functional programming language to think and program functionally.

Functional Programming != Functional Programming Languages

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You don't need to use a functional programming language to think and program functionally.

> Functional Programming != Functional Programming Languages
> (Although functional programming languages force you to think functionally.)

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Rapid Introduction to Haskell: Variables

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Rapid Introduction to Haskell: Variables

```haskell
x :: Integer
x = 3
```

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Rapid Introduction to Haskell: Variables

```haskell
x :: Integer
x = 3

pi :: Double
pi = 3.1415926
```

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Rapid Introduction to Haskell: Variables

```
x :: Integer
x = 3

pi :: Double
pi = 3.1415926

b1, b2 :: Bool
b1 = True
b2 = False
```

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Rapid Introduction to Haskell: Arithmetic

Rapid Introduction to Haskell: Arithmetic

```
ex01 = 3 + 2
```

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Rapid Introduction to Haskell: Arithmetic

```
ex01 = 3 + 2
ex02 = 19 - 27
```

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Rapid Introduction to Haskell: Arithmetic

```
ex01 = 3 + 2
ex02 = 19 - 27
ex03 = 2.35 * 8.6
```

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Rapid Introduction to Haskell: Arithmetic

```
ex01 = 3 + 2
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ex03 = 2.35 * 8.6
ex04 = 8.7 / 3.1
```

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Rapid Introduction to Haskell: Arithmetic

```
ex01 = 3 + 2
ex02 = 19 - 27
ex03 = 2.35 * 8.6
ex04 = 8.7 / 3.1
ex05 = div 12 5
```

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Rapid Introduction to Haskell: Arithmetic

```
ex01 = 3 + 2
ex02 = 19 - 27
ex03 = 2.35 * 8.6
ex04 = 8.7 / 3.1
ex05 = div 12 5
ex06 = 7 ^ 222
```

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Rapid Introduction to Haskell: A Note on Parentheses

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Many languages use parentheses to call functions.

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```
sum(3, 4, 5);
```

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In Haskell, we omit the parentheses and use spaces instead.

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Rapid Introduction to Haskell: A Note on Parentheses

Many languages use parentheses to call functions.

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In Haskell, we omit the parentheses and use spaces instead.

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However, we may need parentheses to compute an argument before calling the function.

Rapid Introduction to Haskell: A Note on Parentheses

Many languages use parentheses to call functions.

```
sum(3, 4, 5);
```

In Haskell, we omit the parentheses and use spaces instead.

```
sum 3 4 5
```

However, we may need parentheses to compute an argument before calling the function.

```
sum (1 + 2) 4 5
```

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```
ex07 = True && False
```

Rapid Introduction to Haskell: Boolean Logic

```
ex07 = True && False
ex08 = not (True || False)
```

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Rapid Introduction to Haskell: Boolean Logic

```
ex07 = True && False
ex08 = not (True || False)
ex09 = ('a' == 'a')
```

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Rapid Introduction to Haskell: Boolean Logic

```
ex07 = True && False
ex08 = not (True || False)
ex09 = ('a' == 'a')
ex10 = (16 /= 3)
```

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Rapid Introduction to Haskell: Boolean Logic

```
ex07 = True && False

ex08 = not (True || False)

ex09 = ('a' == 'a')

ex10 = (16 /= 3)

ex11 = "Haskell" > "C++"
```

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Rapid Introduction to Haskell: Functions

Rapid Introduction to Haskell: Functions

```haskell
doubleMe :: Integer -> Integer
doubleMe x = x + x
```

Rapid Introduction to Haskell: Functions

```haskell
doubleMe :: Integer -> Integer
doubleMe x = x + x

quadrupleMe :: Integer -> Integer
quadrupleMe x = doubleMe (doubleMe x)
```

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Rapid Introduction to Haskell: Functions

We can also write functions with local variables.

Rapid Introduction to Haskell: Functions

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```
hypotenuse :: Double -> Double -> Double
hypotenuse length width = sqrt squaredHypotenuse
  where squaredHypotenuse = length^2 + width^2
```

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We can also write functions with local variables.

```
hypotenuse :: Double -> Double -> Double
hypotenuse length width = sqrt squaredHypotenuse
  where squaredHypotenuse = length^2 + width^2

hypotenuse2 :: Double -> Double -> Double
hypotenuse2 length width =
  let squaredHypotenuse = length^2 + width^2 in
  sqrt squaredHypotenuse
```

Outline

Rapid Introduction to Haskell: Types

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```haskell
type Position = (Double, Double)
```

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Rapid Introduction to Haskell: Types

```haskell
type Position = (Double, Double)

position :: Position
position = (1.25, 2.75)
```

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Rapid Introduction to Haskell: Types

```haskell
type Position = (Double, Double)

position :: Position
position = (1.25, 2.75)

magnitude :: Position -> Double
magnitude (x, y) = sqrt (x * x + y * y)
```

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Rapid Introduction to Haskell: Types

```haskell
type Position = (Double, Double)

position :: Position
position = (1.25, 2.75)

magnitude :: Position -> Double
magnitude (x, y) = sqrt (x * x + y * y)
```

(We will return to this example later.)

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Rapid Introduction to Haskell: Types

A Person has a name, age, and favorite color.

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```
type Name = String
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Rapid Introduction to Haskell: Types

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```
type Age = Integer
```

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A Person has a name, age, and favorite color.

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type Name = String
type Age = Integer
type Color = String
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A Person has a name, age, and favorite color.

```
type Name = String

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data Person = Person Name Age Color
```

Rapid Introduction to Haskell: Types

A Person has a name, age, and favorite color.

```
type Name = String

type Age = Integer

type Color = String

data Person = Person Name Age Color

glenn :: Person
glenn = Person "Glenn R. Fisher" 22 "Green"
```

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Rapid Introduction to Haskell: Types

A Person has a name, age, and favorite color.

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type Name = String

type Age = Integer

type Color = String

data Person = Person Name Age Color

glenn :: Person
glenn = Person "Glenn R. Fisher" 22 "Green"

favoriteColor :: Person -> Color
favoriteColor (Person name age color) = color
```

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A Person has a name, age, and favorite color.

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type Name = String

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data Person = Person Name Age Color

glenn :: Person
glenn = Person "Glenn R. Fisher" 22 "Green"

favoriteColor :: Person -> Color
favoriteColor (Person name age color) = color

favoriteColor glenn == "Green"
```

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Position

Let's create a Position type and write associated functions.

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```
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type Distance = Double
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{- reflect returns a new Position reflected over the origin -}
reflect :: Position -> Position
reflect (x, y) = (-x, -y)
```

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{- magnitude returns a Position's distance from the origin -}
magnitude :: Position -> Distance
magnitude (x, y) = sqrt (x * x + y * y)
```

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{- magnitude returns a Position's distance from the origin -}
magnitude :: Position -> Distance
magnitude (x, y) = sqrt (x * x + y * y)

{- translate returns a new Position translated by an offset -}
translate :: Position -> Position -> Position
translate (x, y) (offsetX, offsetY) = (x + offsetX, y + offsetY)
```

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Example: Region

Let's create a Region type and write associated functions.

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Let's create a Region type and write associated functions.
How should we represent a region in 2D space?

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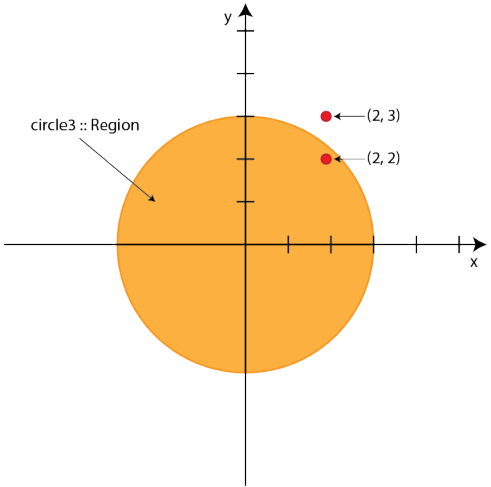

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Example: Region

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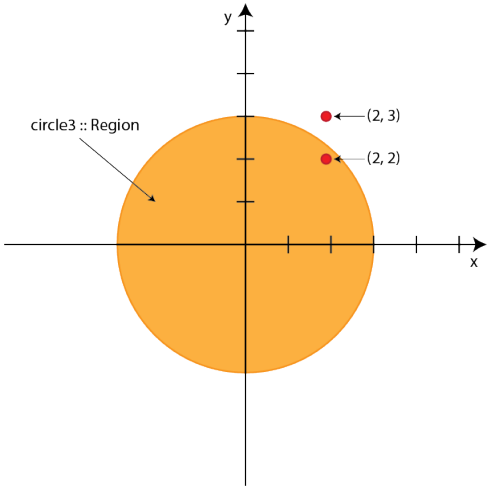


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type Region = Position -> Bool
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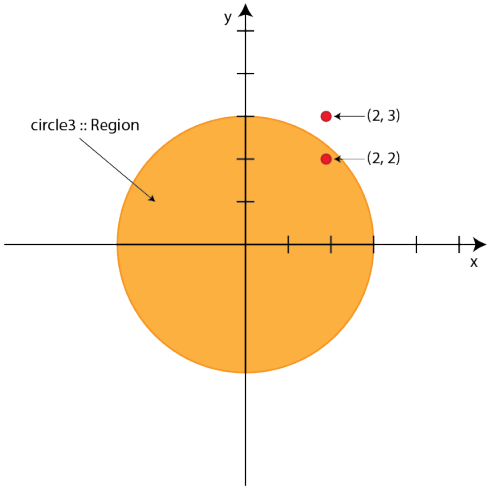


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```
circle3 (2, 2) == True
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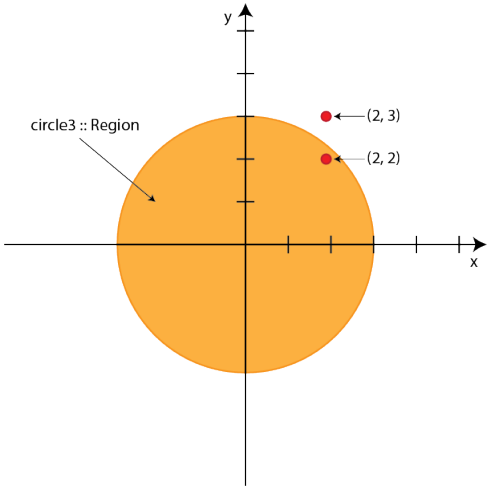


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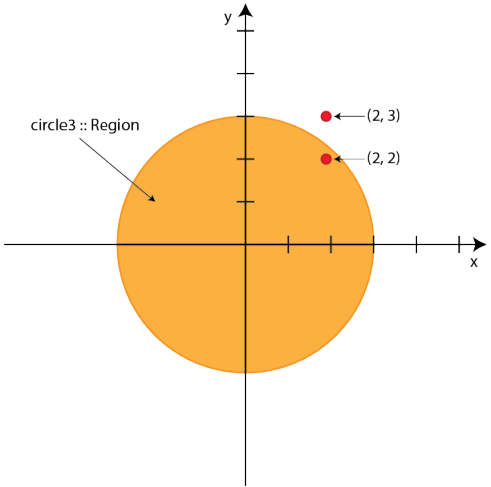


```
type Region = Position -> Bool

circle3 (2, 2) == True

circle3 (2, 3) == False

circle3 :: Region
circle3 position = (magnitude position <= 3.0)
```

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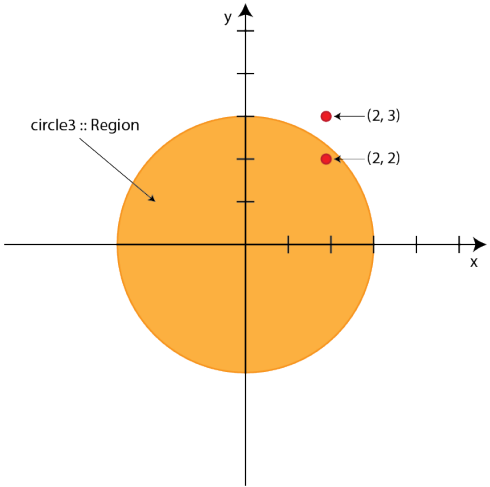


```
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circle4 :: Region
circle4 position = (magnitude position <= 4.0)
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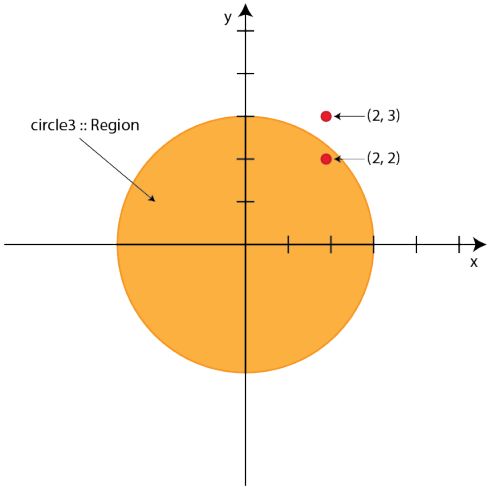


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circle3 :: Region
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circle4 :: Region
circle4 position = (magnitude position <= 4.0)

circle :: Distance -> Region
circle radius = fun
  where fun position = (magnitude position <= radius)
```

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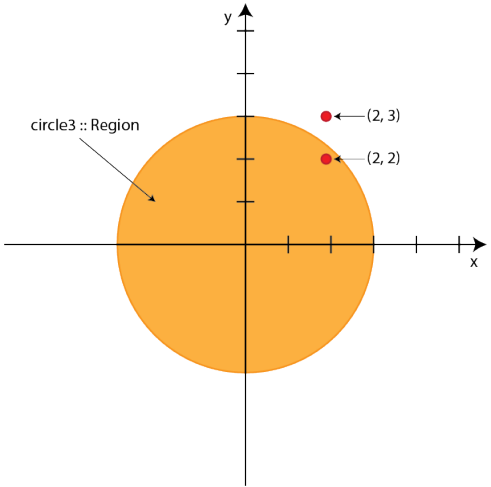


```
type Region = Position -> Bool

circle3 (2, 2) == True

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circle3 :: Region
circle3 position = (magnitude position <= 3.0)

circle4 :: Region
circle4 position = (magnitude position <= 4.0)

circle :: Distance -> Region
circle radius = fun
  where fun position = (magnitude position <= radius)

easyCircle3 = circle 3.0
easyCircle4 = circle 4.0
```

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Example: Region

What if we don't want our circle to be centered at the origin?

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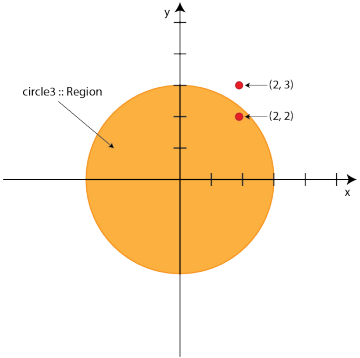

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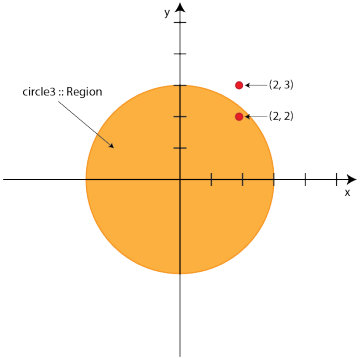

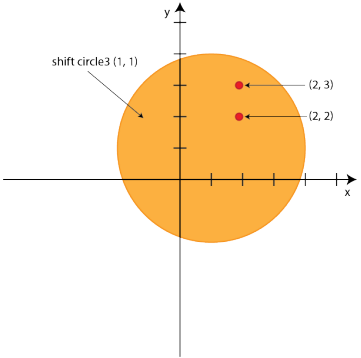

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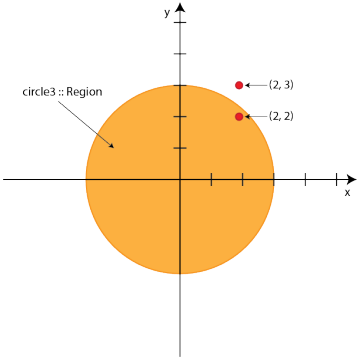

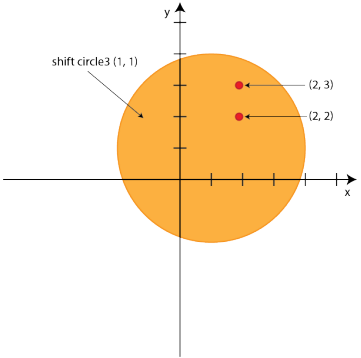


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{- shift transforms a region by translating it by an offset -}
shift :: Region -> Position -> Region
```

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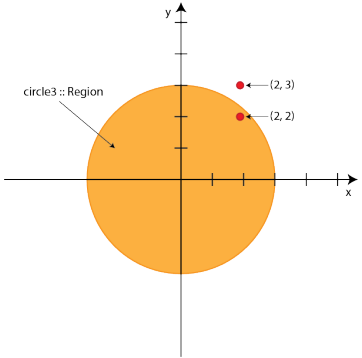

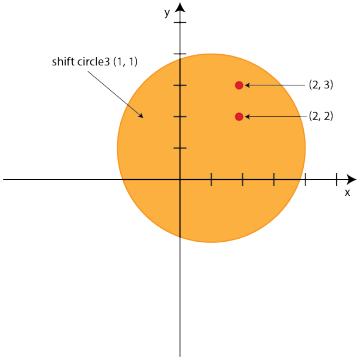


```haskell
{- shift transforms a region by translating it by an offset -}
shift :: Region -> Position -> Region
shift region offset = fun
  where fun position = region (translate position (reflect offset))
```

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Example: Region

What if we want the region outside of the circle?

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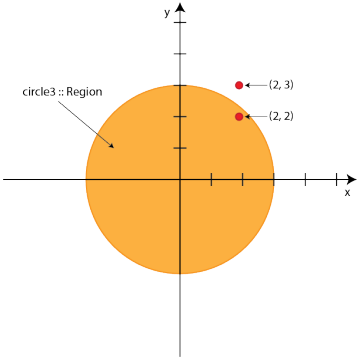

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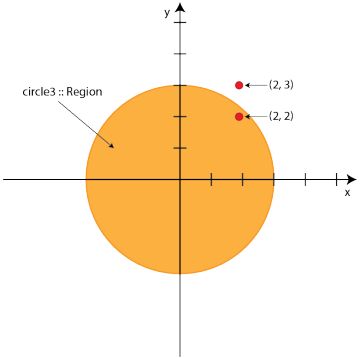

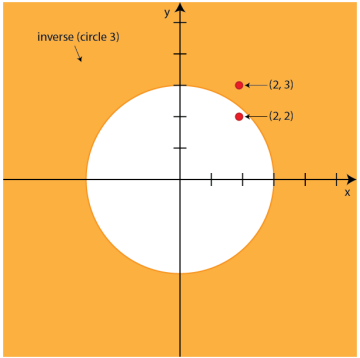

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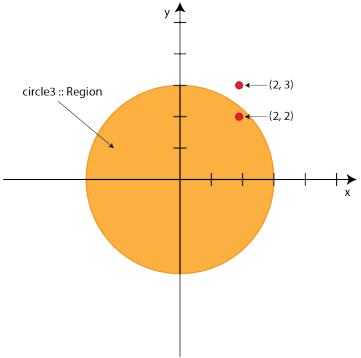

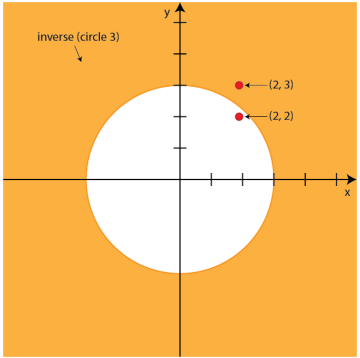


```
{- invert transforms a region by inverting the set of Positions that it contains -}
invert :: Region -> Region
```

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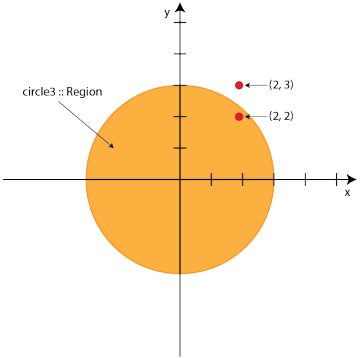

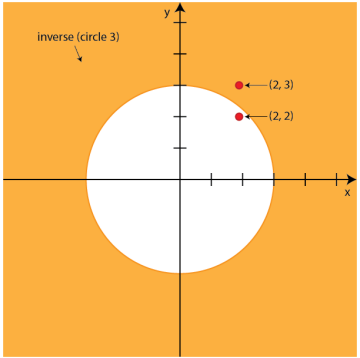


```
{- invert transforms a region by inverting the set of Positions that it contains -}
invert :: Region -> Region
invert region = fun
    where fun position = not (region position)
```

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Example: Region

Can we combine regions to create new regions?

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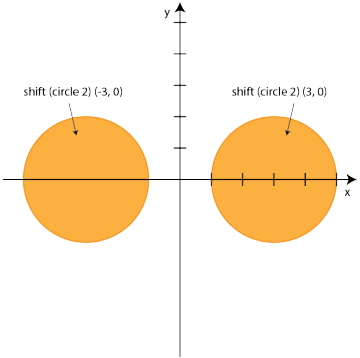

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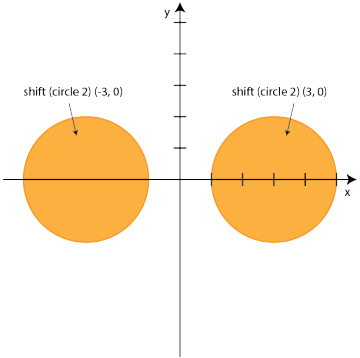

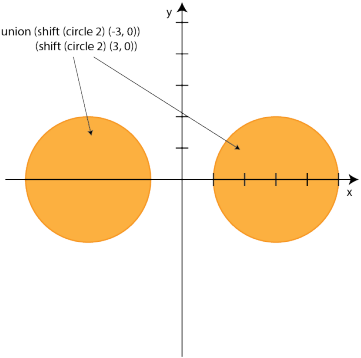

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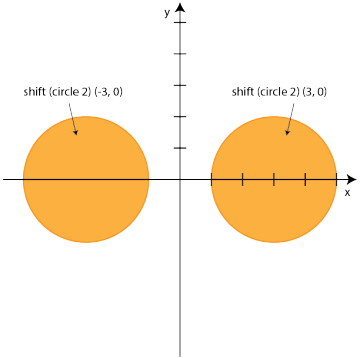

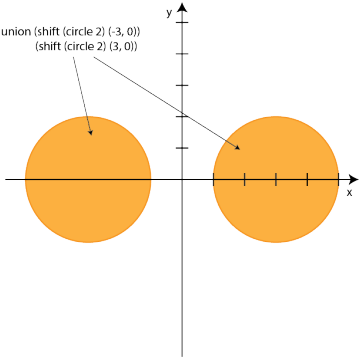


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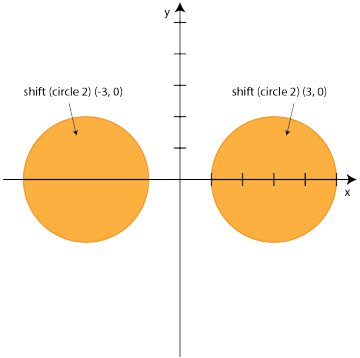

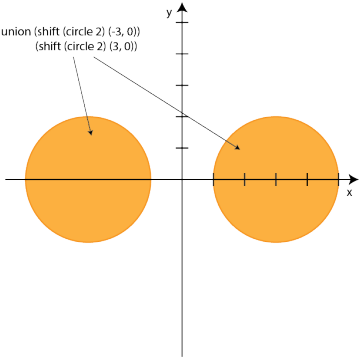


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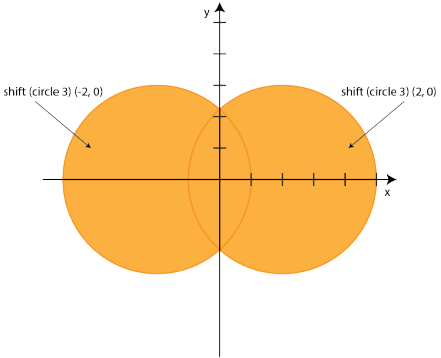

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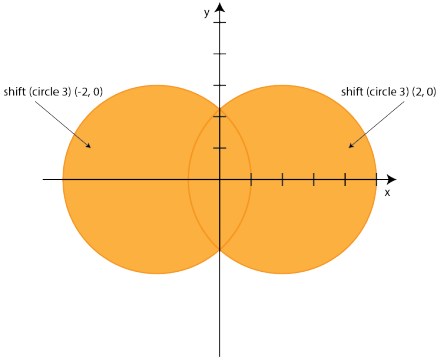

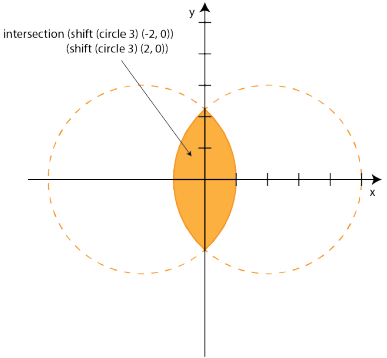

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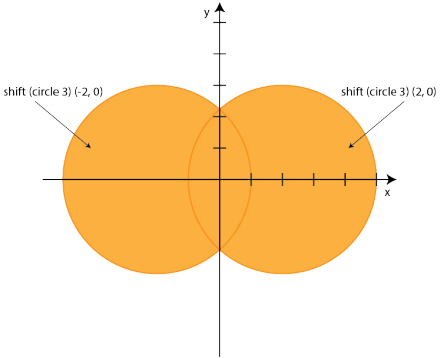

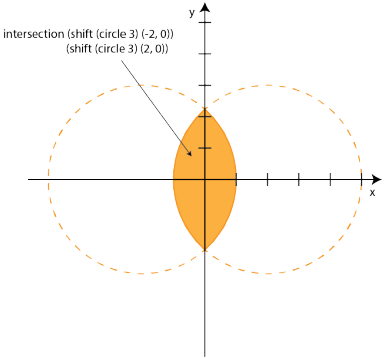


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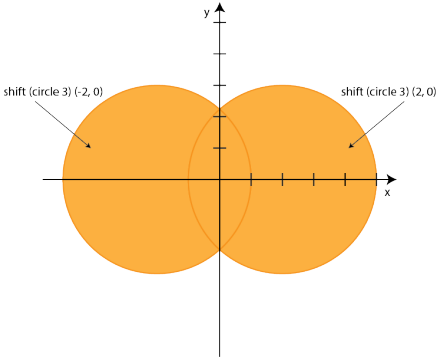

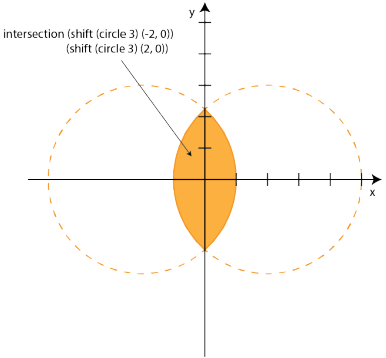


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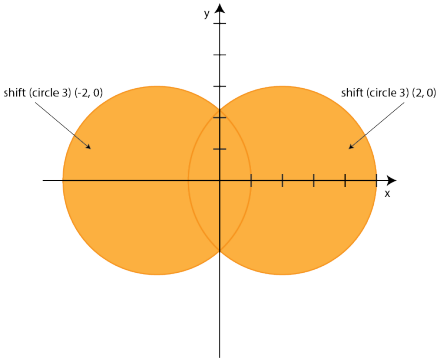

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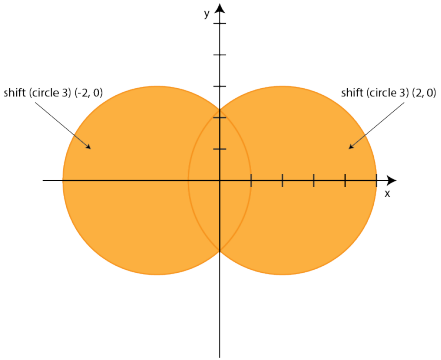

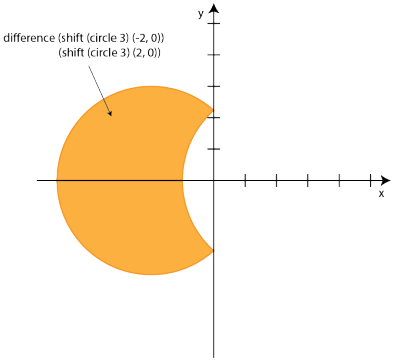

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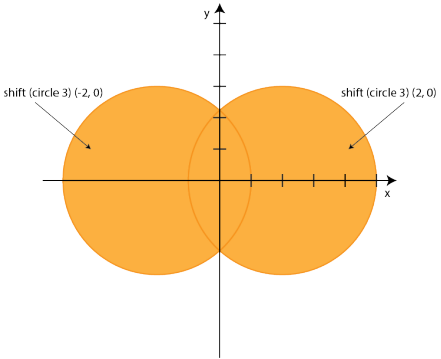

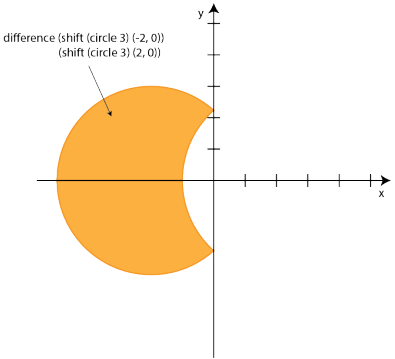


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{- difference constructs a new Region containing all the Positions
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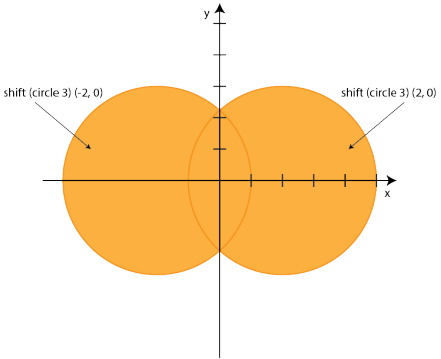

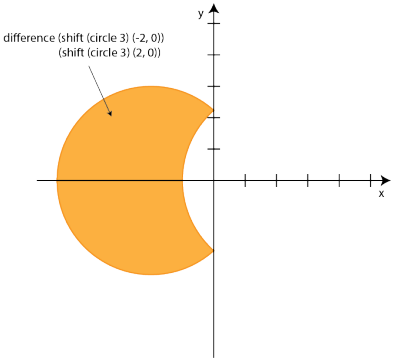


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circle :: Distance -> Region
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{- invert transforms a region by inverting the set of Positions that it contains -}
invert :: Region -> Region
invert region = fun
    where fun position = not (region position)
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Summary

Functional programming is a different way to think about writing programs.

- **First-Class Functions**: A function can return another function or accept functions as parameters.
- **Lack of State**: There are no assignment statements. Everything is immutable.
- **Expressions (Not Instructions)**: Functions compute results instead of performing actions.
- **Comprehensive Type System**: Create types and catch errors at compile time.

Hopefully this talk helped you develop **intuition** behind these ideas.

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