Functional Programming in Typed Racket

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GitHub Course Page

All slides and course materials are available on:

https://github.com/fbie/parallel-functional-lectures

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- Used in financial industry, modern compilers and more.
- Jobs in functional programming pay better!

Typed Racket

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- Functional language, no side-effects (mostly).
- Good for meta-programming (we won't look at that).

Hello World in Typed Racket

```racket
;; Tell run-time which language to use.
#lang typed/racket

;; Now print something.
(print "Nihao!")
```

A More Interesting Program

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;; Define x as the result of the computation.
(define x (* (+ 2 4) (+ 42 9)))
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We can check its value in the interactive mode:

```
> x
59
```

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`(+ x y)`	$\Rightarrow$	$x + y$
`(> x y)`	$\Rightarrow$	$x > y$
`(/ x y)`	$\Rightarrow$	$\frac{x}{y}$
`(f x y)`	$\Rightarrow$	$f(x, y)$

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Some functions are *variadic*:

`(+ x y z)` $\Rightarrow$ $x + y + z$

Local Bindings

Just like local variables in Java, but you can never change them!

```
#lang typed/racket

(let ([x (* 2 16)]
      [y (* 3 17)])
    (+ x y))
```

What does this program do?

Note: You cannot reference `x` and `y` after the last closing parenthesis of the `let` expression!

The Same Program in Java

```
int x = 2 * 16;
int y = 3 * 17;
x + y;
```

A First Function

```
#lang typed/racket

(: times-two (-> Number Number))
(define (times-two x)
  (* 2 x))
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- Functions need no return statement. Their return value is the last executed statement!

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Several new things on this slide:

- Functions need no return statement. Their return value is the last executed statement!
- Type annotations start with `:` and describe the type of a symbol.
- The type of `times-two` is *Number* $\rightarrow$ *Number*.

Types in Typed Racket

We write the function type $A \rightarrow B$ as:

```
(-> A B)
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where `A` is the parameter type and `B` is the return type.

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```
(-> A B C)
```

Which types are parameter types, which ones are return types?

A Second Function

```
(: funny (-> Number Number))
(define (funny x)
  (if (< x 0)
      (- x)
      x))
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Conditionals have the form `(if B E1 E2)`.

Polymorphic Types

Polymorphic types in Typed Racket are very explicit:

```
(: twice (All (A) (-> A (Pairof A A))))
(define (twice a)
  (cons a a))
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It’s just like generic types in Java!

The Same Program in Java

```
public static Pairof<A, A> twice(A a) {
  return new Pairof<A, A>(a);
}
```

Note: There is no build-in pair type in Java :(

Local Bindings, Revisited

Let's turn our local binding example into a function!

```
(: two-three-sum (-> Number Number Number))
(define (two-three-sum a b)
  (let ([x (* 2 a)]
        [y (* 3 b)])
      (+ x y)))
```

Local Bindings, Revisited

Let's turn our local binding example into a function!

```
(: two-three-sum (-> Number Number Number))
(define (two-three-sum a b)
  (let ([x (* 2 a)]
        [y (* 3 b)])
    (+ x y)))
```

Now, we can call it like any other function:

```
> (two-three-sum 1 1)
5
> (two-three-sum 20 20)
100
```

Anonymous Functions

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2
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Here, we have defined a lambda expression and applied it to the value `2`. We call this function the *identity function*.

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```

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We will often come across lambda expressions in functional programming!

Structs in Typed Racket

Structs are containers for values.

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(struct (myNumberBox
                [v : Number]))

(struct (myNumberStringBox
               ([n : Number] [s : String])))
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             ([n : Number] [s : String])))
```

We can also use type polymorphism here:

```
(struct (A) (myPolyBox [value : A]))
```

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- You can download Racket from
  - `racket-lang.org`

Java Equivalent to Maybe

```
public abstract class Maybe<A> {}

public class None<A> extends Maybe<A> {
  public None() {}
}
public class Some<A> extends Maybe<A> {
  public final A a;
  public Some(A a) {
    this.a = a;
  }
}
```

Java Equivalent to Cons List

```java
public abstract class LinkedList<A> {}

public class Nil<A> extends LinkedList<A> {
  public Nil() {}
}
public class Cons<A> extends LinkedList<A> {
  public final A a;
  public final LinkedList<A> tail;

  public Cons(A a, LinkedList<A> tail) {
    this.a = a;
    this.tail = tail;
  }
}
```

Java Equivalent to Binary Tree

```
public abstract class BinaryTree<A> {}

public class Leaf<A> extends BinaryTree<A> {
  public final A a;
  public Leaf(A a) {
    this.a = a;
  }
}
public class Node<A> extends BinaryTree<A> {
  public final BinaryTree<A> left, right;
  public Node(BinaryTree<A> left,
              BinaryTree<A> right) {
    this.left = left; this.right = right;
  }
}
```