Functional Programming in Typed Racket

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- If you do not understand what I say or if I speak too fast, **please tell me right away!**

GitHub Course Page

All slides and course materials are available on:

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

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- Makes it easier to think about what a program does.
- Parallel in its nature $\rightarrow$ easy to parallelize (next lecture).
- 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

```
;; This is a comment!
;; Tell the 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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Operators are also just functions:

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

Some functions are *variadic*:

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

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

```
#lang typed/racket

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

```
public static void main(String[] args) {
  int x = 2 * 16;
  int y = 3 * 17;
  System.out.println(x + y);
}
```

A First Function

```racket
#lang typed/racket

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(define (times-two x)
  (* 2 x))
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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

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

where `A` is the parameter type and `B` is the return type.

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```
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```

where `A` is the parameter type and `B` is the return type.

```
(-> 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 :(

State is Immutable!

You cannot change a variable's value. Instead, use **recursion**:

```
(: is-even? (-> Integer Boolean))
(define (is-even? n)
  (if (< 0 n)
      (is-even? (- n 2))
      (= n 0)))
```

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Now, we can call the function:

```
> (is-even? 1)
#f
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```

Now, we can call the function:

```
> (is-even? 1)
#f

> (is-even? 2048)
#t
```

The Same Program in Java

```
public static bool isEven(int n) {
  while (0 < n)
    n = n - 2;
  return n == 0;
}
```

Anonymous Functions

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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*. It is the same as

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We will often come across lambda expressions in functional programming!

Structs in Typed Racket

Structs are containers for values.

```
(struct (myNumberBox
                [v : Number]))

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

We can also use type polymorphism here:

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

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  - `github.com/fbie/parallel-functional-programming`
- 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;
  }
}
```

Singly-Linked Cons List 1/2

```
(define xs (cons 'a (cons 'b
    (cons 'c (cons 'd (cons 'e '()))))))
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Get the first element of `xs`, the "head":

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> (first xs)
'a
> (cdr xs)
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Get the first element of `xs`, the “head”:

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> (first xs)
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```
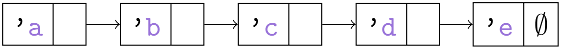

Get the remaining part of `xs`, the “tail”:

```
> (rest xs)
'('b 'c 'd 'e)
> (cdr xs)
'('b 'c 'd 'e)
```

Singly-Linked Cons List 2/2

References to tail **cannot be changed**, because all **references are immutable**:



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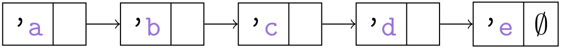

If we want to remove an element, we must build a new list, but we can re-use the tail of the element that we have deleted:

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(remove xs 'c)
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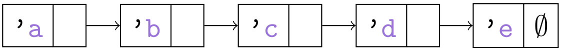

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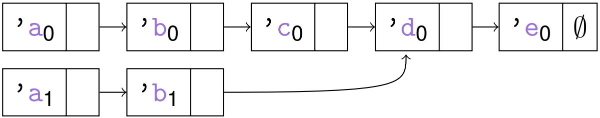

Java Equivalent to Cons List

```
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;
  }
}
```