

# Concepts of programming languages

## Rust

Floris Schild, Mats Veldhuizen, Ruben Schenkuizen, Tobias van Driessel, Tom Freijsen





# Presentation Schedule

- ▶ Background
- ▶ Design principles
- ▶ What problems does Rust solve and how?
- ▶ Practical details



# Background

- ▶ Personal project of Mozilla employee
- ▶ Sponsored by Mozilla Research
- ▶ First stable release (1.0) in 2015
- ▶ Used in Firefox and by Dropbox
- ▶ Most loved programming language - SO Developer Survey



# Quick Overview

- ▶ Statically typed
- ▶ Functional **and** Imperative paradigms
- ▶ Strict language



# Beautiful Quotes

Mozilla Research:

*“Rust is a systems programming language that runs blazingly fast, prevents segfaults, and guarantees thread safety.”*

*“It fuses the expressive and intuitive syntax of high-level languages with the control and performance of a low-level language.”*



# Features



Universiteit Utrecht

[Faculty of **Science**  
**Information and Computing Sciences**]

# Features

- ▶ Zero-cost abstractions





# Features

- ▶ Zero-cost abstractions
- ▶ Move semantics



# Features

- ▶ Zero-cost abstractions
- ▶ Move semantics
- ▶ Guaranteed memory safety



# Features

- ▶ Zero-cost abstractions
- ▶ Move semantics
- ▶ Guaranteed memory safety
- ▶ Threads without data races



# Features

- ▶ Zero-cost abstractions
- ▶ Move semantics
- ▶ Guaranteed memory safety
- ▶ Threads without data races
- ▶ Trait-based generics



# Features

- ▶ Zero-cost abstractions
- ▶ Move semantics
- ▶ Guaranteed memory safety
- ▶ Threads without data races
- ▶ Trait-based generics
- ▶ Pattern matching



# Features

- ▶ Zero-cost abstractions
- ▶ Move semantics
- ▶ Guaranteed memory safety
- ▶ Threads without data races
- ▶ Trait-based generics
- ▶ Pattern matching
- ▶ Type inference



# Features

- ▶ Zero-cost abstractions
- ▶ Move semantics
- ▶ Guaranteed memory safety
- ▶ Threads without data races
- ▶ Trait-based generics
- ▶ Pattern matching
- ▶ Type inference
- ▶ Minimal runtime



# Features

- ▶ Zero-cost abstractions
- ▶ Move semantics
- ▶ Guaranteed memory safety
- ▶ Threads without data races
- ▶ Trait-based generics
- ▶ Pattern matching
- ▶ Type inference
- ▶ Minimal runtime
- ▶ Efficient C bindings





# Variable bindings

- ▶ Use *let* keyword to create binding
- ▶ Bindings are immutable by default
- ▶ Lhs not a name, but a *pattern*
- ▶ Type annotations

```
fn main() {  
    let y = 3;  
}  
  
let (a, b) = (1, 2);  
let mut x : u8 = 10; // Make x mutable  
x = 255;
```



# Functions

- ▶ Use *fn* keyword
- ▶ Statements vs expressions

```
fn square(x: i32) -> i32 {  
    x * x // Expression  
}  
  
fn printSomething() {  
    println!("Something"); // Statement  
}
```



# Arrays and tuples

Arrays can be created like this:

```
let mut y = [4, 5, 6];  
let second = y[1];  
let mut z = [1; 10]; // Ten elements initialized to 1
```

Tuples are created as follows:

```
let mut tuple = (1, 2);  
let x = tuple.0;  
let y = tuple.1;  
  
println!("Value of y is {}", y);  
  
let (x, y, z) = (1, 2, 3); // Destructured tuple
```



# Control flow

- ▶ *If, else, else if...*
- ▶ *Loops, like loop, while and for*

```
let x = 2;  
let y = if x == 3 { 4 } else { 5 };  
loop { println!("Infinite loop"); }
```

```
for x in 1..10 {}  
for (index, value) in (1..10).enumerate() { }
```

```
let a = [1, 2, 3, 4, 5];  
for elem in a.iter() {  
    println!("the value is: {}", elem);  
}
```



# Vectors

- ▶ Dynamic arrays
- ▶ Allocated on heap (as opposed to arrays)

```
let mut v = vec![1,2,3]
```

```
for i in v {} // For loop takes ownership
```

```
for i in &v {} // Reference
```

```
for i in &mut v {} // Mutable reference
```



# Structs

- ▶ Comparable to classes.
- ▶ Can also have methods and associated functions

```
struct Point {  
    x: i32,  
    y: i32,  
}
```

```
impl Point {  
    fn print_xy(&self) {  
        println!("x is {}, y is {}", self.x, self.y);  
    }  
}
```

```
let point = Point { x: 3, y: 6 };  
point.print_xy(); // Shows x is 3, y is 6.
```



# Match

- ▶ Comparable to switch
- ▶ Allows matching on expressions

```
let x: u32 = 3;
```

```
match x {  
    1 => println!("one"),  
    2 => println!("two"),  
    _ => println!("three or more"),  
}
```



- ▶ Define type and enumerate on its variants

```
enum Choice {  
    Milk(i32),  
    Tea(String),  
}
```

```
let m = Choice::Milk(20);
```





# Generics

- Generic structs, enums and functions.

```
fn takes_anything<T, U>(x: T, u: U) {}
```

```
struct Value<T> {  
    value : T  
}
```

```
enum Choice<T> {  
    Milk(T),  
}
```



# Traits

- ▶ Somewhat comparable to an interface
- ▶ Use trait bounds on generics

```
struct Square {  
    side: f64,  
}  
  
trait HasArea {  
    fn area(&self) -> f64;  
}  
  
impl HasArea for Square {  
    fn area(&self) -> f64 {  
        self.side * self.side  
    }  
}  
  
fn print_area<T: HasArea>(shape: T) {  
    println!("This shape has an area of {}", shape.area());  
}
```



# Much, much more..

- ▶ Smart pointers
- ▶ Concurrency
- ▶ Closures
- ▶ ...



# Memory management

Different systems

- ▶ Garbage collection



# Memory management

Different systems

- ▶ Garbage collection
- ▶ Smart pointers (reference counting)



# Memory management

Different systems

- ▶ Garbage collection
- ▶ Smart pointers (reference counting)
- ▶ Ownership



# Memory management

Different systems

- ▶ Garbage collection
- ▶ Smart pointers (reference counting)
- ▶ Ownership

**Key difference:** When are objects on the heap deallocated?



# Ownership

- ▶ Every value has one variable that is its owner.





# Ownership

- ▶ Every value has one variable that is its owner.

*Example*

```
let x = String::from("hello");
```

The variable `x` is the owner of the value 5.

The string object will be deallocated when `x` goes out of scope.



# Ownership

*Another example*

```
fn say_hello(name: String) {  
    println!("Hello {}", name);  
}
```

```
let x = String::from("Wouter");  
say_hello(x);  
say_hello(x); // Error!
```



# Ownership

*Another example*

```
fn say_hello(name: String) {  
    println!("Hello {}", name);  
}
```

```
let x = String::from("Wouter");  
say_hello(x);  
say_hello(x); // Error!
```

The ownership is passed into `say_hello`, which deallocates our string when its scope ends.



# Borrowing

- ▶ Pass a reference to the function
- ▶ Ownership is not transferred
- ▶ Immutable (by default)

```
fn say_hello(name: &String) {  
    println!("Hello {}", name);  
}
```

```
let x = String::from("Wouter");  
say_hello(&x);  
say_hello(&x); // Works!
```



# Mutable references

```
fn double(value: &mut isize) {  
    *value = *value * 2;  
}
```

```
let mut x: isize = 3;  
double(&mut x);  
// x = 6
```



- ▶ Taking a reference to part of a collection

```
let some_numbers = [0, 1, 2, 3, 4, 5];  
let slice = &some_numbers[0..3]; // [0, 1, 2]
```



# Smart pointers

- ▶ Sometimes you may want more freedom
- ▶ For these situations, reference counting is also possible in Rust

```
let a = Rc::new(String::from("Blue"));
```



# Smart pointers

- ▶ Box
- ▶ Enables recursive data types





# Smart pointers

```
enum List {  
    Cons(usize, Box<List>),  
    Nil  
}  
  
let list = List::Cons(1,  
    Box::new(List::Cons(2,  
    Box::new(List::Cons(3,  
    Box::new(List::Nil))))));  
  
// list = (1 : (2 : (3 : [])))
```



# Reference counting using smart pointers

```
struct Node {  
    value: isize,  
    next: Vec<Rc<Node>>  
}
```

```
let d = Rc::new(Node { value: 8, next: vec![] });  
let b = Rc::new(Node { value: 3, next: vec![Rc::clone(&d)] });  
let c = Rc::new(Node { value: 5, next: vec![Rc::clone(&d)] });  
let a = Rc::new(Node { value: 2, next: vec![Rc::clone(&b),  
                                             Rc::clone(&c)] });
```



# What problems does Rust (intend to) solve?

- ▶ Memory safety
- ▶ “Fearless” concurrency
- ▶ Performance



# Memory safety

## Null pointers

- ▶ Easy to forget
- ▶ The Option enum (similar to Maybe in Haskell)
- ▶ The Result enum



# Memory safety

Null pointers

```
enum Option<T> {  
    Some(T),  
    None,  
}  
  
enum Result<T, E> {  
    Ok(T),  
    Err(E),  
}
```



# Memory safety

## Dangling references

- ▶ No garbage collector!
- ▶ Borrowing rules/Lifetimes



# Memory safety

## Buffer overruns

- ▶ Safety
- ▶ Index in array
- ▶ Compile/Runtime checks



# “Fearless” concurrency

## Borrowing rules

- ▶ Only one owner
- ▶ No aliasing
- ▶ Easier debugging





# “Fearless” concurrency

## Message passing

```
let (tx, rx) = mpsc::channel();

thread::spawn(move || {
    let val = 5;
    tx.send(val).unwrap();
});

let received = rx.recv().unwrap();
```



# “Fearless” concurrency

## Shared state

```
let m = Mutex::new(0);  
  
thread::spawn(move || {  
    let mut num = m.lock().unwrap();  
    *num = 5;  
});
```



# Performance

- ▶ No garbage collector
- ▶ Fewer run time checks



# Practical

- ▶ Mature & intuitive package manager (cargo)
- ▶ Lots of libraries from a vibrant community
- ▶ i.a. IDE priority this year
- ▶ Basic linting and debugging
- ▶ Get started on <https://doc.rust-lang.org>
- ▶ Used because of safety, performance and being practical



# Conclusion

- ▶ Fast & safe systems programming language
- ▶ Ownership & borrowing paradigms



# Questions



Universiteit Utrecht

[Faculty of **Science**  
Information and Computing **Sciences**]