The Rust Programming Language

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The Rust Programming Language

These slides are also online at

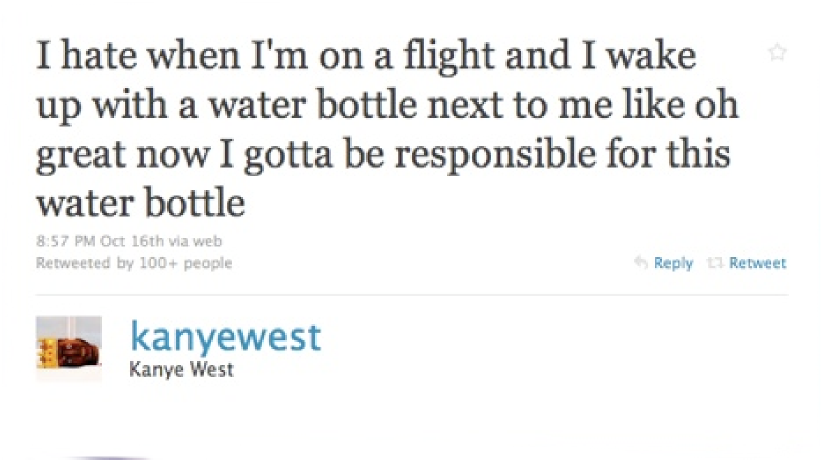
`http://github.com/aisamanra/rust-examples`

The Rust Programming Language

A new systems programming language being developed by Mozilla Research, with an emphasis on correctness while still allowing for very low-level programing by emphasizing *zero-cost abstractions*.

Low-Level Programming

Low-Level Programming



I hate when I'm on a flight and I wake up with a water bottle next to me like oh great now I gotta be responsible for this water bottle

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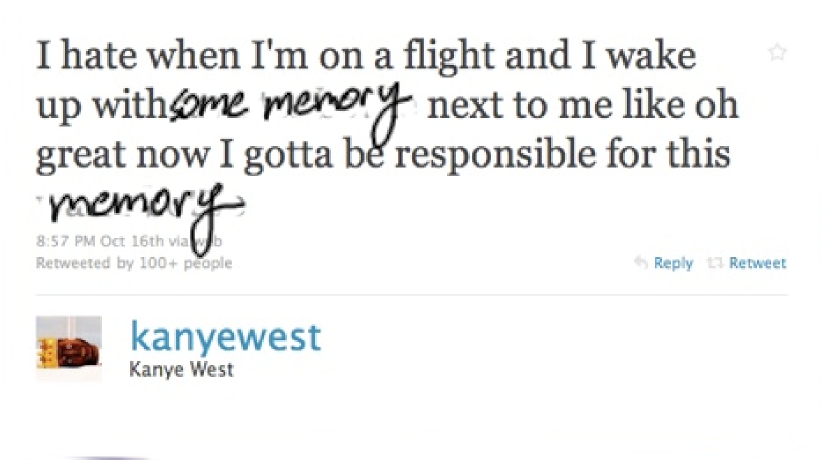
Kanye West

Low-Level Programming



I hate when I'm on a flight and I wake up with some memory next to me like oh great now I gotta be responsible for this memory

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Kanye West

Systems Programming Languages

System software is computer software designed to operate and control the computer hardware and to provide a platform for running application software, and includes such things as operating systems, utility software, device drivers, compilers, and linkers.
—Wikipedia

"Systems programs" means "programs where the constant factors are important".
—Comment by `neelk` on Lambda the Ultimate

Systems Programming Languages

Example Program

A program that:

- Defines a `point` struct.
- Gives that `point` struct two machine integers as fields.
- Defines an `add` function that takes and returns two `point`s *by value*.
- Has a `main` function that:
  - Creates a `point` on the stack
  - Creates a `point` on the heap
  - Adds the two (after dereferencing the second)
  - Prints the result
  - Frees the second point

Systems Programming Languages

C

```c
typedef struct { int x, y; } point;

point add(point a, point b) {
  point result = { a.x + b.x, a.y + b.y };
  return result;
}

void main(int argc, char* argv[]) {
  point a = { 1, 2 };
  point* b = malloc(sizeof(point));
  b->x = 4; b->y = 3;
  point c = add(a, *b);
  printf("{.x = %d, .y = %d}\n", c.x, c.y);
  free(b);
}
```

Systems Programming Languages

C++

```
struct point {
  int x, y;
  point(int _x, int _y) { x = _x; y = _y; }
  point add(point other) {
    return point(x + other.x, y + other.y);
  }
};
int main(int argc, char* argv[]) {
  point a(1, 2);
  point* b = new point(4, 3);
  point c = a.add(*b);
  cout << "{ .x = " << c.x;
  cout << ", .y = " << c.y << " }" << endl;
  delete b;
}
```

Systems Programming Languages

Go

```go
type Point struct { X, Y int }

func (a Point) add(b Point) Point {
    return Point{ a.X + b.X, a.Y + b.Y }
}

func main() {
    a := Point{1, 2}
    b := new(Point)
    b.X, b.Y = 4, 3
    fmt.Println(a.add(*b))
    // No free, because Go is garbage-collected
}
```

Systems Programming Languages

D

```
struct Point {
  int x, y;
  Point add(Point other) {
    return Point(this.x + other.x, this.y + other.y);
  }
}

void main() {
  Point a = Point(1, 2);
  Point* b = cast(Point*)GC.malloc(Point.sizeof);
  b.x = 4; b.y = 3;
  writeln(a.add(*b));
  GC.free(b);
}
```

Systems Programming Languages

Nim

```
type Point = tuple[x: int, y: int]

proc add(a: Point, b: Point): Point =
  (x: a.x + b.x, y: a.y + b.y)

var a : Point
var b : ptr Point

a = (x: 1, y: 2)
b = cast[ptr Point](alloc(sizeof(Point)))
b.x = 4
b.y = 3
echo(add(a, b[]))
dealloc(b)
```

Systems Programming Languages

Rust

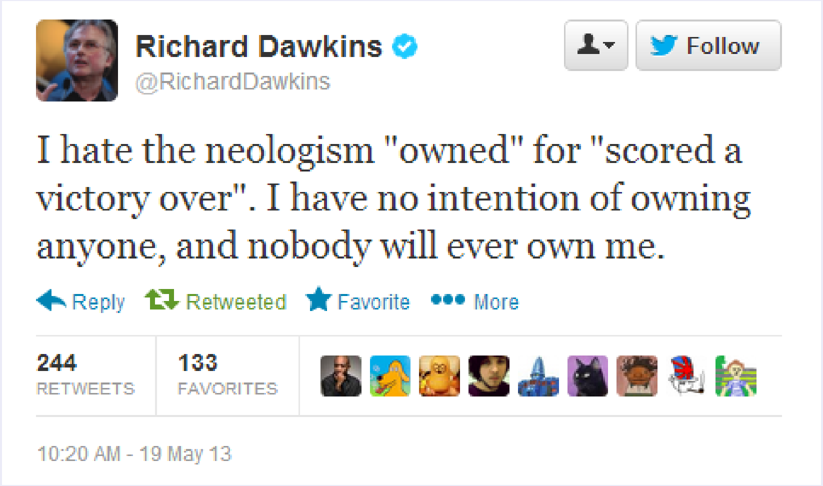
```rust
#[derive(Debug,Clone,Copy)]
struct Point { x: isize, y: isize }

fn add(l: Point, r: Point) -> Point {
    Point { x: l.x + r.x, y: l.y + r.y }
}

fn main() {
    let a = Point { x: 1, y: 2 };
    let b = Box::new(Point { x: 4, y: 3 });
    println!("{:?}", add(a, *b));
}
```

What Makes Rust Interesting

Ownership



Richard Dawkins
@RichardDawkins

I hate the neologism "owned" for "scored a victory over". I have no intention of owning anyone, and nobody will ever own me.

244 RETWEETS
133 FAVORITES

10:20 AM - 19 May 13

Preliminary Zero

Mutability

```
fn factorial(n: usize) -> usize {
  let result = 1;
  while n > 0 {
    result *= n;
    n -= 1;
  }
  result
}
```

Preliminary Zero

Mutability is NOT THE DEFAULT

```
fn factorial(n: usize) -> usize {
  let result = 1;
  while n > 0 {
    result *= n;  /* ERROR */
    n -= 1;       /* ERROR */
  }
  result
}
```

Preliminary Zero

Mutability is Opt-In

```
fn factorial(mut n: usize) -> usize {
  let mut result = 1;
  while n > 0 {
    result *= n;
    n -= 1;
  }
  result
}
```

Preliminary One

Polymorphism (although not on this slide)

```
fn i32_id(a: i32) -> i32 {
  a
}

fn make_i32_pair(left: i32, right: i32) -> (i32, i32) {
  (left, right)
}
```

Preliminary One

Polymorphism (this slide is, like, *totally* polymorphic)

```
fn id<T>(a: T) -> T {
  a
}

fn make_pair<A, B>(left: A, right: B) -> (A, B) {
  (left, right)
}
```

Preliminary Two

Traits

```
struct MyNum { num: i32 }

trait Sayable {
  fn say(&self);
}

impl Sayable for MyNum {
  fn say(&self) {
    println!(".oO( MyNum {{ num: {:?} }} )", self.num);
  }
}
```

Preliminary Two

Traits

```
fn main() {
  (MyNum { num: 3 }).say();
}
```

Output

```
.oO( MyNum { num: 3 } )
```

Preliminary Three

Traits *and* Polymorphism

```
fn say_twice<T: Sayable>(t: T) {
  t.say(); t.say();
}

fn main() {
  say_twice(MyNum { num: 7 });
}
```

Output

```
.oO( NyNum { num: 7 } )
.oO( NyNum { num: 7 } )
```

Preliminary Three

Traits *and* Polymorphism

```
fn print_eq<A: Eq + Sayable>(left: A, right: A) {
  if left == right {
    println!("these are equal:");
    left.say();
    right.say();
  } else {
    println!("these are not equal:");
    left.say();
    right.say();
  }
}
```

Preliminary Four

Built-In Traits

```
/* slightly simplified from the real definition */
trait PartialEq {
  fn eq(&self, other: &Self) -> bool;
  fn ne(&self, other: &Self) -> bool;
}

/* no more methods, but more laws */
trait Eq: PartialEq { }
```

Preliminary Four

Implementing Built-In Traits

```
struct MyNum { num: i32 }

impl PartialEq for MyNum {
  fn eq(&self, other: &MyNum) -> bool {
    self.num == other.num
  }
}

impl Eq for MyNum { }
```

Preliminary Four

Implementing Built-In Traits Automatically

```
/* or just this */
#[derive(PartialEq,Eq)]
struct MyNum { num: i32 }
```

Preliminary Four

Format-String-Related Traits

```
/* in the stdlib: */
trait Debug {
  fn fmt(&self, &mut Formatter) -> Result;
}

/* so, on on our type: */
#[derive(Debug)]
struct MyNum { num: i32 }
```

What Makes Rust Interesting

Ownership

```
#[derive(Debug)]
struct MyNum { num: i32 }

fn main() {
  let x = MyNum { num: 2 };

  println!("x = {:?}", x);
  /* prints "x = MyNum { num: 2 }" */
}
```

What Makes Rust Interesting

Ownership

```
#[derive(Debug)]
struct MyNum { num: i32 }

fn main() {
  let x = MyNum { num: 2 };
  let y = x;
  println!("x = {:?}", x);
  /* doesn't compile */
}
```

What Makes Rust Interesting

Ownership

```
#[derive(Debug)]
struct MyNum { num: i32 }

fn main() {
  let x = MyNum { num: 2 };
  let y = x; /* <- value moves here */
  println!("x = {:?}", x);

}
```

What Makes Rust Interesting

Ownership

```
#[derive(Debug)]
struct MyNum { num: i32 }

fn main() {
  let x = MyNum { num: 2 };
  let y = x;
  println!("x = {:?}", x);
  /* so it does not live until the print */
}
```

What Makes Rust Interesting

Ownership — Explicit Cloning

```
#[derive(Debug, Clone)]
struct MyNum { num: i32 }

fn main() {
  let x = MyNum { num: 2 };
  let y = x.clone(); /* explicit clone */
  println!("x = {:?}", x);
  /* but this works! */
}
```

What Makes Rust Interesting

Ownership — Implicit Copying

```
#[derive(Debug, Clone, Copy)]
struct MyNum { num: i32 }

fn main() {
  let x = MyNum { num: 2 };
  let y = x; /* implicit copy */
  println!("x = {:?}", x);
  /* as does this! */
}
```

What Makes Rust Interesting

Ownership — Destructors

```
#[derive(Debug)]
struct MyNum { num: i32 }

impl Drop for MyNum {
  fn drop(&mut self) {
    println!("dropping: {:?}", self)
  }
}

fn main() {
  let x = MyNum { num: 2 };
  println!("x = {:?}", x);
}
```

What Makes Rust Interesting

Ownership — Destructors

```
fn main() {
  let x = MyNum { num: 2 };
  println!("x = {:?}", x);
}
```

Output

```
x = MyNum { num: 2 }
dropping: MyNum { num: 2 }
```

What Makes Rust Interesting

Ownership — Special Clones

```rust
#[derive(Debug)]
struct MyNum { num: i32 }

impl Clone for MyNum {
  fn clone(&self) -> Self {
    println!("Cloning a MyNum...");
    MyNum { num: self.num }
  }
}

fn main() {
  let x = MyNum { num: 2 };
  let y = x.clone();
  println!("x = {:?}", x);
}
```

What Makes Rust Interesting

Owned Pointers — “Boxes”

```
fn main() {

  let x = Box::new(5);

  println!("x + 1 = {:?}", *x + 1);


}
```

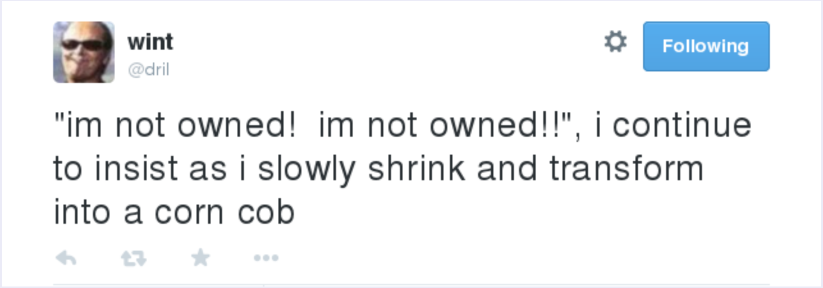
What Makes Rust Interesting

Owned Pointers — “Boxes”

```
fn main() {
  /* this acts like a `malloc` */
  let x = Box::new(5);
  /* this dereferences the pointer */
  println!("x + 1 = {:?}", *x + 1);
  /* as soon as ownership passes out
   * of scope, the box is freed */
}
```

What Makes Rust Interesting

References


wint
@dril

"im not owned! im not owned!!", i continue to insist as i slowly shrink and transform into a corn cob

What Makes Rust Interesting

References

```
#[derive(Debug)]
struct MyNum { num: i32 }

fn some_func(_: MyNum) {
  println!("yeah, whatevs");
}

fn main() {
  let x = MyNum { num: 2 };
  some_func(x);
  println("{:?}", x);

}
```

What Makes Rust Interesting

References

```
#[derive(Debug)]
struct MyNum { num: i32 }

fn some_func(_: MyNum) {
  println!("yeah, whatevs");
}

fn main() {
  let x = MyNum { num: 2 };
  some_func(x);
  println("{:?}", x);
  /* ERROR: use of moved value */
}
```

What Makes Rust Interesting

References

```
#[derive(Debug)]
struct MyNum { num: i32 }

fn some_func(_: MyNum) -> MyNum {
  println!("yeah, whatevs");
}

fn main() {
  let x = MyNum { num: 2 };
  let y = some_func(x.clone());
  println("{:?}", y);
  /* works---but so tedious! */
}
```

What Makes Rust Interesting

References

```
#[derive(Debug,Clone)]
struct MyNum { num: i32 }

fn some_func(_: MyNum) {
  println!("yeah, whatevs");
}

fn main() {
  let x = MyNum { num: 2 };
  some_func(x.clone());
  println("{:?}", x);
  /* works---but not what we want */
}
```

What Makes Rust Interesting

References

```rust
#[derive(Debug)]
struct MyNum { num: i32 }

fn some_func(_: &MyNum)  {
  println!("yeah, whatevs");
}

fn main() {
  let x = MyNum { num: 2 };
  some_func(&x);
  println("{:?}", x);
  /* works! */
}
```

What Makes Rust Interesting

Dangling References...?

```
fn main() {
  let mut my_ref: &i32 = &5;
  {
    let x = 7;
    my_ref = &x;
  }
  println!("{:?}", my_ref);
}
```

What Makes Rust Interesting

Dangling References... are statically prevented

```
fn main() {
  let mut my_ref: &i32 = &5;
  {
    let x = 7;
    my_ref = &x; /* ERROR: does not live long enough */
  }
  println!("{:?}", my_ref);
}
```

What Makes Rust Interesting

"The Borrow Checker"

```
fn main() {
  let mut my_vec = vec![];
  {
    let x = 7;
    my_vec.push(&x); /* also a problem */
  }
  println!("{:?}", my_vec);
}
```

What Makes Rust Interesting

Lifetime Quandary

```
fn keep_left<T>(left: &T, right: &T) -> &T {
  left
}
```

What Makes Rust Interesting

Lifetime Quandary

```
fn keep_left<'l, 'r, T>(left: &l T,
                        right: &r T) -> &l T {
  left
}
```

A Slightly Longer Example

A Linked List

```
#[derive(Debug)]
enum List<T> {
  Cons(T, Box<List<T>>),
  Nil,
}

fn cons<T>(car: T, cdr: List<T>) -> List<T> {
  List::Cons(car, Box::new(cdr))
}

fn nil<T>() -> List<T> {
  List::Nil
}
```

A Slightly Longer Example

A Linked List

```
fn head<T>(list: &List<T>) -> Option<&T> {
  match *list {
    Nil => None,
    Cons(ref x, _) => Some(&x),
  }
}
```

A Slightly Longer Example

A Linked List Lifetime

```
fn main() {
  let mut h = None;
  {
    let lst = cons("this",
                cons("that",
                  cons("the other",
                    nil())));
    h = head(lst);
  }
  println!("{:?}", h);
}
```

A Slightly Longer Example

Linked List: A Lifetime Original Picture

```
fn head<'a, T>(list: &'a List<T>) -> Option<&'a T> {
  match *list {
    Nil => None,
    Cons(ref x, _) => Some(&x),
  }
}
```

A Slightly Longer Example

Linked List: A Lifetime Original Picture

```
fn polycephaly<T>(left: &List<T>, right: &List<T>)
  -> Option<(&T, &T)> {
  match (*left, *right) {
    (List::Nil, List::Nil) => None,
    (List::Cons(ref x, _),
     List::Cons(ref y, _)) => Some(y, x)
  }
}
```

A Slightly Longer Example

You May Find Yourself Living in a Shotgun Shack

```
fn polycephaly<'l, 'r, T>(left: &'l List<T>,
                          right: &'r List<T>)
  -> Option<(&'r T, &'l T)> {
    match *left {
        List::Cons(ref x, _) => match *right {
            List::Cons(ref y, _) => Some((y, x)),
            _ => None,
        },
        _ => None,
    }
}
```