Rust

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cs380p

Outline

Rust!

Overview

Decoupling Shared, Mutable, and State

Channels and Synchronization

Acknowledgements:

- https://www.slideshare.net/nikomatsakis/rust-concurrency-tutorial-2015-1202
- Thanks Nikolas Matsakis!

Rust Motivation

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Locks’ litany of problems:

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Solution: don't use locks

- non-blocking
- Data-structure-centric
- HTM
- blah, blah, blah..

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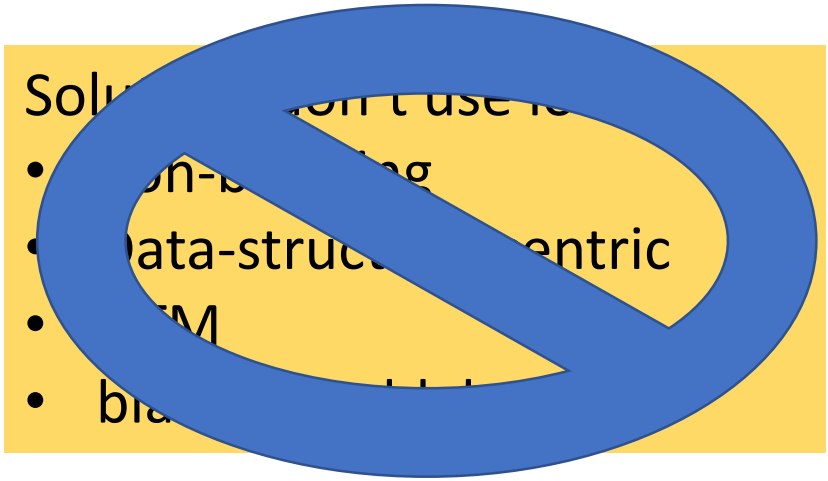

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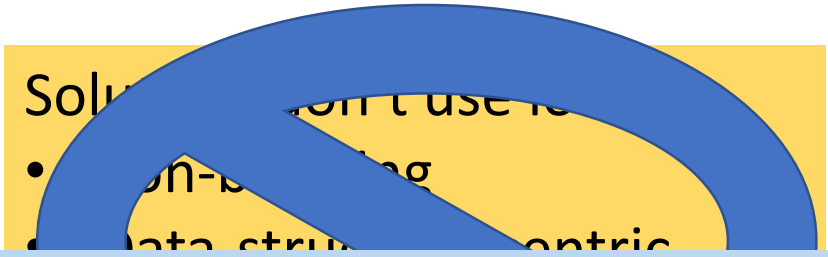

Shared mutable state requires locks

- So…separate sharing and mutability
- Use type system to make concurrency safe
- Ownership
- Immutability
- Careful library support for sync primitives

Rust Goals

Multi-paradigm language modeled after C and C++

- Functional, Imperative, Object-Oriented

Primary Goals:

- Safe Memory Management
- Safe Concurrency and Concurrent Controls

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Be Fast: systems programming
Be Safe: don’t crash

Memory Management

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Rust: a “safe” environment for memory

- No Null, Dangling, or Wild Pointers

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Objects are *immutable* by default

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Declared variables must be initialized prior to execution

- A bit of a pain for static/global state

Unsafe

Credit: http://www.skiingforever.com/ski-tricks/

Unsafe

Functions determined unsafe via specific behavior

- Deference null or raw pointers
- Data Races
- Type Inheritance

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Using “unsafe” keyword → bypass compiler enforcement

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The user deals with the integrity of the code

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Other Relevant Features

- First-Class Functions and Closures
  - Similar to Lua, Go, …
- Algebraic data types (enums)
- Class Traits
  - Similar to Java interfaces
  - Allows classes to share aspects

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Hard to use/learn without awareness of these issues

Concurrency

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Tasks → Rust’s threads

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Each task → stack and a heap

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Task States: Running, Blocked, Failing, Dead

- Failing task: interrupted by another process
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Task States: Running, Blocked, Failing, Dead

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Scheduling

- Each task → finite time-slice
- If task doesn't finish, deferred until later
- "M:N scheduler"

Hello World

```
fn main() {
    println!("Hello, world!")
}
```

Ownership

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Ownership/Borrowing →

No need for a runtime

Memory safety (GC)

Data-race freedom

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MM Options:

- Managed languages: GC
- Native languages: manual management
- Rust: 3rd option: ***track ownership***

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MM Options:

- Managed languages: GC
- Native languages: manual management
- Rust: 3rd option: ***track ownership***

- Each value in Rust has a variable called its *owner*.
- There can only be one owner at a time.
- Owner goes out of scope→value will be dropped.

Ownership/Borrowing

```
fn main() {
  let name = format!("...");
  helper(name);
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fn helper(name: String) {
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error[E0382]: use of moved value: `name`
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24 |     let name = format!("...");
   |         ---- move occurs because `name` has type `std::string::String`, which does not implement the `Copy` trait
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What kinds of problems might this prevent?

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What kinds of problems might this prevent?

Pass by reference takes “ownership implicitly” in other languages like Java

Shared Borrowing

```
fn main() {
  let name = format!("...");
  helper(&name);
  helper(&name);
}
```

```
fn helper(name: &String) {
  println!(“{}”, name);
}
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Shared Borrowing

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fn main() {
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Lend the string

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Take a reference to a String

Why does this fix the problem?

Shared Borrowing with Concurrency

```
fn main() {
  let name = format!("...");
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}
```

```
fn helper(name: &String) {
  thread::spawn(||{
    println!("{}", name);
  });
}
```

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Lifetime `static` required

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error[E0621]: explicit lifetime required in the type of `name`
  --> play.rs:11:18
   |
10 | fn helper(name: &String) -> thread::JoinHandle<()> {
   |                 ------- help: add explicit lifetime `'static` to the type of `name`: `&'static std::string::String`
11 |     let handle = thread::spawn(move ||{
   |                  ^^^^^^^^^^^^^ lifetime `'static` required
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Does this prevent the exact same class of problems?

Clone, Move

```
fn main() {
  let name = format!("...");
  helper(name.clone());
  helper(name);
}
```

```
fn helper(name: String) {
  thread::spawn(move || {
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Clone, Move

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fn main() {
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fn helper(name: String) {
  thread::spa[redacted]| {
    println!("{}", name);
  });
}
```

Explicitly take ownership

Clone, Move

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fn main() {
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```

Ensure concurrent owners
Work with different copies

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Is this better?

Clone, Move

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Is this better?

```
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```

Copy versus Clone:

Default: Types cannot be copied

- Values move from place to place
- E.g. file descriptor

Clone: Type is expensive to copy

- Make it explicit with clone call
- e.g. Hashtable

Copy: type implicitly copy-able

- e.g. u32, i32, f32, …

```
#[derive(Clone, Debug)]
```

Mutability

```
struct Structure {
    id: i32,
    map: HashMap<String, f32>,
}

impl Structure {
    fn mutate(&self, name: String, value: f32) {
        self.map.insert(name, value);
    }
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```

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```

Error: cannot be borrowed as mutable

```
error[E0596]: cannot borrow `self.map` as mutable, as it is behind a `&` reference
  --> play.rs:16:9
   |
15 |     fn mutate(&self, name: String, value: f32) {
   |               ----- help: consider changing this to be a mutable reference: `&mut self`
16 |         self.map.insert(name, value);
   |         ^^^^^^^^ `self` is a `&` reference, so the data it refers to cannot be borrowed as mutable
```

Mutability

```
struct Structure {
    id: i32,
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Key idea:

- Force mutation and ownership to be explicit
- Fixes MM *and* concurrency in fell swoop!

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fn main() {
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    let response = rx1.recv().unwrap();
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  let (message, tx1) = rx0.recv().unwrap();
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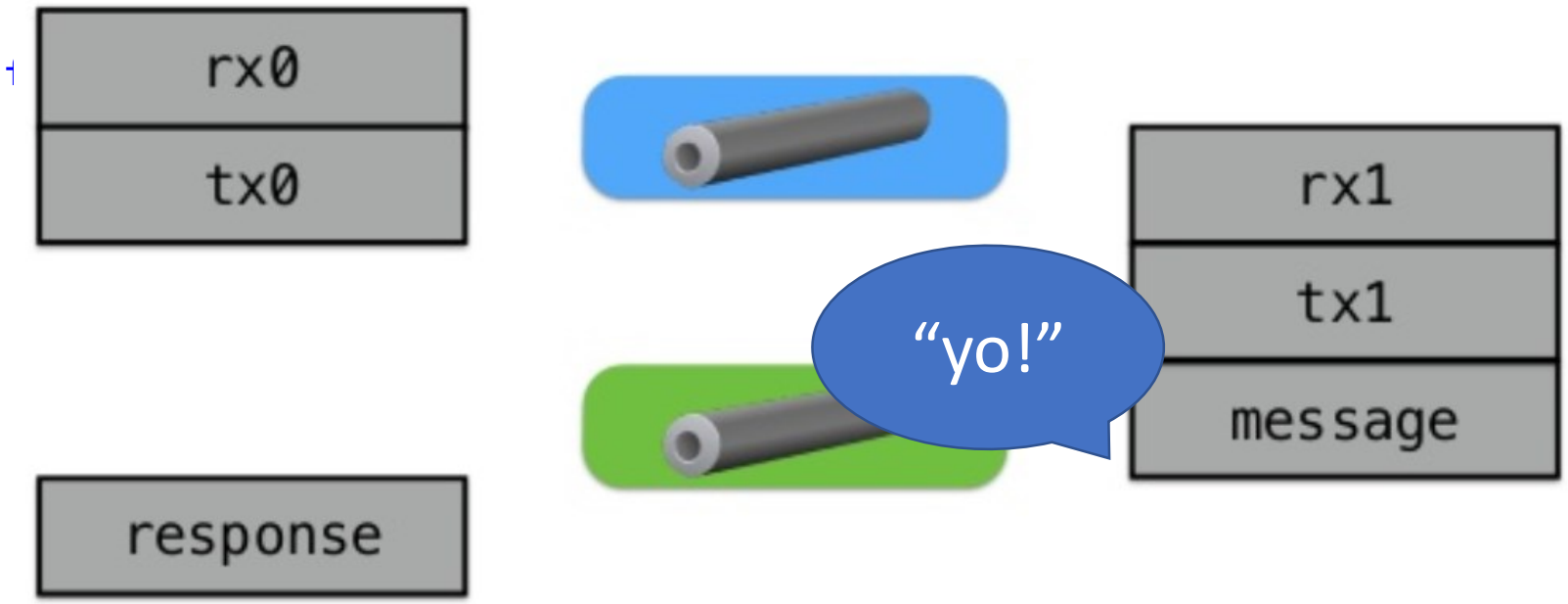


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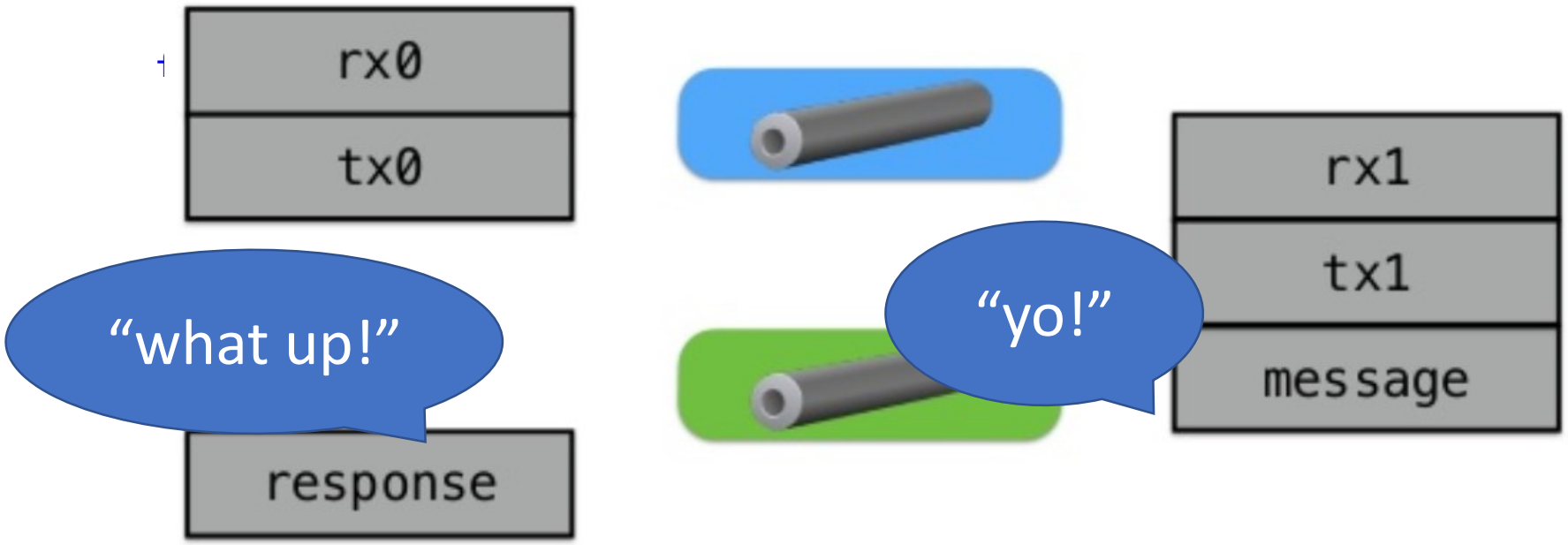


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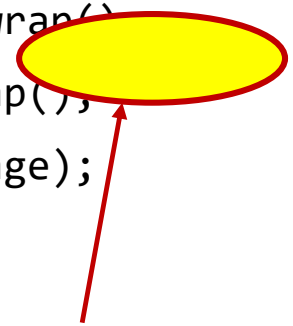

APIs return Option<T>

Sharing State

```
fn main() {
  let var = Structure::new();
  for i in 0..N {
    thread::spawn(move || {
       // ok to mutate var?
    });
  }
}
```

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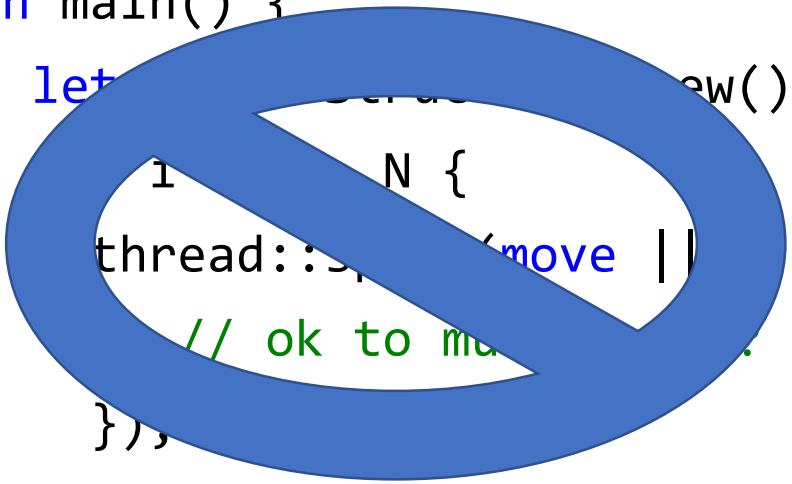

Sharing State: Arc and Mutex

```
fn main() {
  let var = Structure::new();
  let var_lock = Mutex::new(var);
  let var_arc = Arc::new(var_lock);
  for i in 0..N {
    thread::spawn(move || {
      let ldata = Arc::clone(&var_arc);
      let vdata = ldata.lock();
      // ok to mutate var (vdata)!
    });
  }
}
```

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      let ldata = Arc::clone(&var_arc);
      let vdata = [redacted];
      // ok to mutate var (vdata)!
    });
  }
}
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Key ideas:

- Use reference counting wrapper to pass refs
- Use scoped lock for mutual exclusion
- Actually compiles → works 1st time!

Summary

Rust: best of both worlds

- systems vs productivity language

Separate sharing, mutability, concurrency

Type safety solves MM and concurrency

Have fun with the lab!