Rust Presentation

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Section 1

Why Rust

Why Rust

- **Both safe and performant. No tradeoffs.**
- Zero cost abstractions!

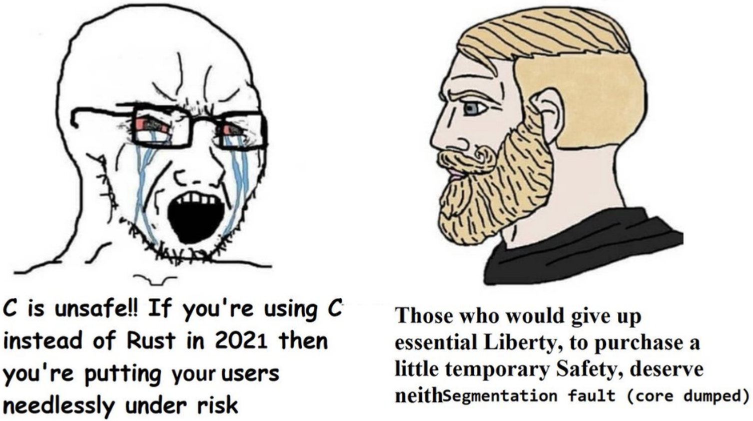
  Really?

  Really!
- Both low-level and high-level

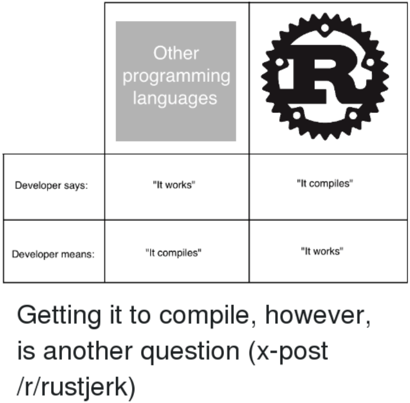
  Write mostly high-level code, go low-level when you need it!

- Memory safety

  Eliminate entire classes of bugs at compile time! You **can't** corrupt memory when using safe Rust!


C is unsafe!! If you're using C instead of Rust in 2021 then you're putting your users needlessly under risk
Those who would give up essential Liberty, to purchase a little temporary Safety, deserve neithSegmentation fault (core dumped)

- Good tooling and helpful compiler



	Other programming languages	R
Developer says:	"It works"	"It compiles"
Developer means:	"It compiles"	"It works"

Getting it to compile, however, is another question (x-post /r/rustjerk)

Rust's focus on safety famously makes implementing classical data structures more difficult, eg. writing a linked list is challenging for a beginner.

https://rust-unofficial.github.io/too-many-lists/

Subsection 1

Borrow checking

Borrow checking

In Rust you can have:

- Multiple immutable (or shared) references
- A single mutable (or exclusive) reference

to an object.

PUT EXAMPLE HERE

Move semantics

Move semantics in Rust are better than in C++. Why?

https://www.thecodedmessage.com/posts/cpp-move/

Short version:

In Rust, if the object is moved, it can't be accessed anymore

In C++, the moved object is still accessible, but is "empty", you need to explicitly handle that case in the destructor, therefore move semantics are not zero cost

Subsection 2

Rich type system

Rich type system

- Algebraic Data Types
- Generics
- Traits

Traits

Hi! My name is Jason
Ah! Nice to meet you, Jason
Jason
FRIENDS
FAMILY
rust standard library traits
Say Jarvis, wanna hear the difference between AsRef<T> and Borrow<T>?

Figure 1: traits

Traits are like interfaces from Java or Go, but better.

- https://softwareengineering.stackexchange.com/questions/247298/how-are-rust-traits-different-from-go-interfaces#247313
- https://stackoverflow.com/questions/69477460/is-rust-trait-the-same-as-java-interface

In short:

- it gives you a choice between static and dynamic dispatch (static dispatch means bigger code size but faster generics)

```
// fast, bigger code size
fn static_dispatch<T: MyTrait>(arg: T) { }

// slow, less code size, uses Vtable
fn dynamic_dispatch(arg: Box<dyn MyTrait>) { }
```

- object definition / method implementation is decoupled (you implement in impl blocks)

```
#[derive(Debug, Clone, Copy)]
struct Vec3 {
    x: f32,
    y: f32,
    z: f32,
}

impl Add for Vec3 {
    type Output = Vec3;

    fn add(self, rhs: Self) -> Self::Output {
        Vec3 {
            x: self.x + rhs.x,
            y: self.y + rhs.y,
            z: self.z + rhs.z,
        }
    }
}

impl Add<f32> for Vec3 {
    type Output = Vec3;

    fn add(self, rhs: f32) -> Self::Output {
        Vec3 {
            x: self.x + rhs,
            y: self.y + rhs,
            z: self.z + rhs,
        }
    }
}
```

- you can conditionally implement a trait for a type

```
impl<T> Clone for Vec<T> where T: Clone {...}
```

- associated types, fuctions, values

```
trait Iterator {
    type Item;
}

struct Iter<T>;
impl Iterator for Iter<T> {
    type Item = &T;
}

struct IterMut<T>;
impl Iterator for IterMut<T> {
    type Item = &mut T;
}

struct IntoIter<T>;
impl Iterator for IntoIter<T> {
    type Item = T;
}
```

Most important standard library traits:

- Debug: Debug print formatting
- Copy (requires Clone): Types that can be implicitly and trivially copied via bitwise copy
- Clone: Types that can be explicitly cloned by calling `.clone()` on them.
- Send: The type can be safely sent between threads
- Sync: The type can be safely accessed via references from different threads. If `&T` is `Send`, then `Sync` is derived automatically

Comparing values:

- PartialEq: For types that have partial equality
- Eq: For types that have full equality
- PartialOrd: For types with partial ordering (type can be compared if its less, greater, or equal)
- Ord: For types with total ordering (can be sorted)

Also:

- `Sized`: The size of this type is known at compile time. If the type has known size, it can be used as fields in structs or placed on the stack. `?Sized` (maybe sized) means size of type is not known at compile time.

  Unlike previous traits, this is assumed for all types, and only unsized types implement `!Sized` (not sized). Example:

  - https://doc.rust-lang.org/stable/std/primitive.slice.html#impl-Sized
  - https://doc.rust-lang.org/stable/std/primitive.str.html#impl-Sized

  Slices and string slices are not `Sized`, but the references to them are.

We use rich type systems to design APIs that are flexible and simple, but most importantly, correct.

Subsection 3

Algebraic data types

Algebraic data types

What is algebraic data type?

> *In computer programming, especially functional programming and type theory, an algebraic data type is a kind of composite type, i.e., a type formed by combining other types.*

We can combine types in two ways:

- Sum types
- Product types

In other languages, structs/classes are like a product type, but there is no proper sum type.

In Rust, enums are sum types. Enums can contain values.

Example: standard library `Option`/`Result` types.

```
enum Option<T> {
    Some(T),
    None
}

let some_int: Option<i32> = Some(5);
let no_int: Option<i32> = None;

enum Result<T, E> {
    Ok(T),
    Err(E)
}

// Returns string on success. Returns error code on failure.
fn op_that_can_fail -> Result<String, i32> {
    // ...
}

let result = op_that_can_fail();

match result {
    Ok(text) => println!("success: {text}"),
    Err(err_code) => println!("error! code: {err_code}")
}
```

It is impossible to not error check in Rust, because you need to handle the error to access the success value:

```
let text: String = std::fs::read_to_string("file.txt");
println!("{text}");
```

```
error[E0308]: mismatched types
 --> examples/result.rs:2:24
  |
2 |     let text: String = std::fs::read_to_string("file.txt");
  |               ------   ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^ expected struct `String`, found enum `Result`
  |               |
  |               expected due to this
  |
  = note: expected struct `String`
               found enum `Result<String, std::io::Error>`

For more information about this error, try `rustc --explain E0308`.
error: could not compile `rust-demo` due to previous error
```

To unwrap the value on success, but exit the program on failure, use `.unwrap()` or `.expect("your message")`.

```rust
let text: String = std::fs::read_to_string("file.txt").unwrap();
println!("{text}");
```

On failure (eg. when `file.txt` does not exist):

```
thread 'main' panicked at 'called `Result::unwrap()` on an `Err` value: Os { code: 2, kind: NotFound, message: "No such file or
note: run with `RUST_BACKTRACE=1` environment variable to display a backtrace
```

Subsection 4

Generics

Generics

Trait based generics

Subsection 5

Fixing a billion dollar mistake

Fixing a billion dollar mistake

What do we usually use null pointers for in other languages?

- to allocate data on the heap
- to signify the presence/absence of a value

These separate concerns are coupled, so it's not possible to express in the type system:

- An optional value that's on the heap
- A heap-allocated value that's non-optional, always valid

That’s why Rust doesn’t have null.

Short version: for optional values, we use `Option<T>`, for heap allocation, we use `Box<T>`. If we want an optinal heap-allocated value, use `Option<Box<T>>`, which is optimized to use only as much memory as `Option<T>`.

Subsection 6

Standard library and documentation

Standard library and documentation

Rust stdlib has two stdlibs:

- `core`, which is a subset of `std`, targets embedded, doesnt support allocation and shit
- `std`, which is bigger, targets programs running on OSes that provide APIs for memory allocation, file operations, system calls, etc.

Use https://std.rs or https://std.rs/[search term] to search (eg. https://std.rs/vector searches for `vector`)

For documentation of crates, use https://docs.rs

Subsection 7

Crates.io

Crates.io

Crates.io is a public package registry for Rust, so like npm for node. To install the crate to our project, we add it to `Cargo.toml` in the `[dependencies]` section:

```
rand = "0.8.5"
```

Or just use `cargo-edit` program:

```
$ cargo install cargo-edit

$ cargo add rand
```

Subsection 8

Tooling (build system, package manager, rustfmt, clippy)

Section 2

Getting started

Subsection 1

How install?

How install?

Use rustup.rs. It lets you install multiple versions of rust. Usually you'll use stable but sometimes you might want to use features that are still unstable and available only on nightly. Also clippy and rustfmt are parts of the toolchain.

Subsection 2

Linux

Linux

Install via your package manager or https://rustup.rs/ if it's not in your distro's repositories. The website installer will automatically prompt you to install the stable toolchain. If you installed rustup via package manager, install stable toolchain: `rustup toolchain install stable`.

Subsection 3

Windows

Windows

Install via https://rustup.rs. To use MSVC backend, which is recommended, you'll need to have installed either Visual Studio 2015+ C++ workload or VS C++ build tools standalone if you don't use visual studio.

You can also use MinGW, but it won't be covered here.

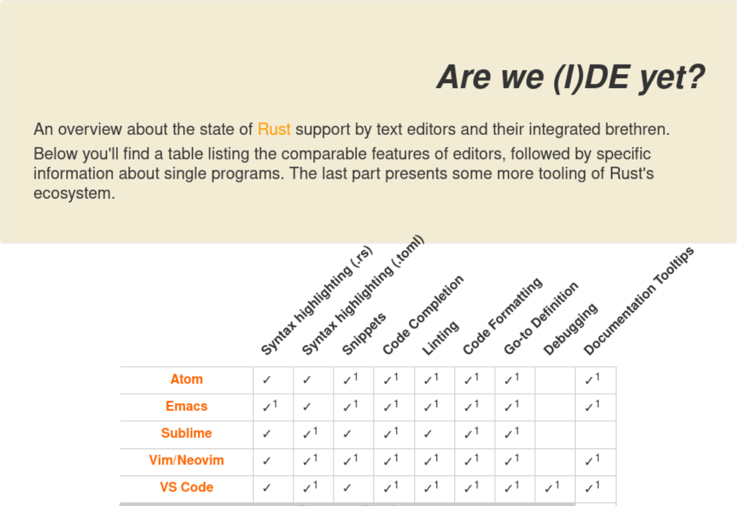
Subsection 4

IDE setup

IDE setup

I personally recommend VS Code with rust-analyzer, but feel free to use something you're comfortable with if it's supported.

List of Rust IDEs/plugis available at: https://areweideyet.com



Are we (I)DE yet?

An overview about the state of Rust support by text editors and their integrated brethren.

Below you'll find a table listing the comparable features of editors, followed by specific information about single programs. The last part presents some more tooling of Rust's ecosystem.

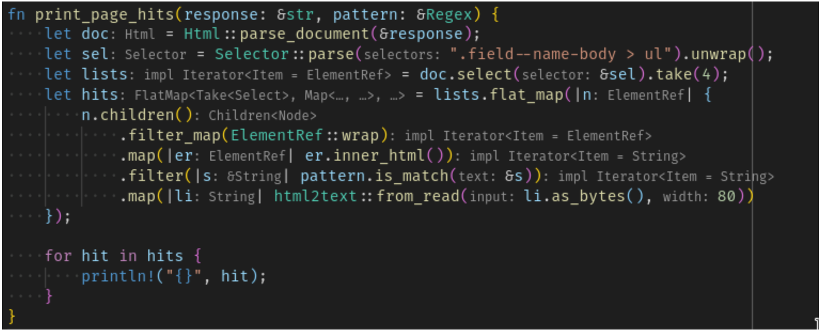
	Syntax highlighting (.rs)	Syntax highlighting (.toml)	Snippets	Code Completion	Linting	Code Formatting	Go-to Definition	Debugging	Documentation Tooltips
Atom	✓	✓	✓[1]	✓[1]	✓[1]	✓[1]	✓[1]		✓[1]
Emacs	✓[1]	✓	✓[1]	✓[1]	✓[1]	✓[1]	✓[1]		✓[1]
Sublime	✓	✓[1]	✓	✓[1]	✓	✓[1]	✓[1]		
Vim/Neovim	✓	✓[1]	✓[1]	✓[1]	✓[1]	✓[1]	✓[1]		✓[1]
VS Code	✓	✓[1]	✓	✓[1]	✓[1]	✓[1]	✓[1]	✓[1]	✓[1]

Subsection 5

VS Code + rust-analyzer

VS Code + rust-analyzer

What does rust-analyzer do?



```
fn print_page_hits(response: &str, pattern: &Regex) {
    let doc: Html = Html::parse_document(&response);
    let sel: Selector = Selector::parse(selectors: ".field--name-body > ul").unwrap();
    let lists: impl Iterator<Item = ElementRef> = doc.select(selector: &sel).take(4);
    let hits: FlatMap<Take<Select>, Map<…, …>, …> = lists.flat_map(|n: ElementRef| {
        n.children(): Children<Node>
            .filter_map(ElementRef::wrap): impl Iterator<Item = ElementRef>
            .map(|er: ElementRef| er.inner_html()): impl Iterator<Item = String>
            .filter(|s: &String| pattern.is_match(text: &s)): impl Iterator<Item = String>
            .map(|li: String| html2text::from_read(input: li.as_bytes(), width: 80))
    });

    for hit in hits {
        println!("{}", hit);
    }
}
```

- type hinitng
- autocomplete
- jump to declaration/definition
- Autoapply suggestions

After you have Rust stable toolchain installed, just install the VS Code rust-analyzer extension. In case of difficulties, refer to the manual.

Subsection 6

Troubleshooting

Troubleshooting

The extension works if the root directory of Rust project is opened in VS Code (the folder that contains `Cargo.toml`). If you have opened a directory with multiple Rust projects, you'll have to manually specify paths for rust-analyzer.

Section 3

Learing Rust

Subsection 1

Basics

Basics

Basics of Rust

Subsection 2

Fearless concurrency

Fearless concurrency

Doing concurrency in Rust relies on `Copy`, `Send`, and `Sync` traits.

Classic "parallelism is hard" example: spawn a bunch of threads that increment a counter.

```
use std::thread;

fn main() {
    let mut counter: i32 = 0;
    let mut handles = Vec::new();

    for _ in 0..4 {
        let handle = thread::spawn(|| {
            for _ in 0..100_000 {
                counter += 1;
            }
        });
        handles.push(handle);
    }

    // join threads before exiting the main function. Without this threads could
    // outlive the main function and we'd get another error
    for handle in handles {
        handle.join().unwrap();
    }

    println!("{counter}");
}
```

Output:

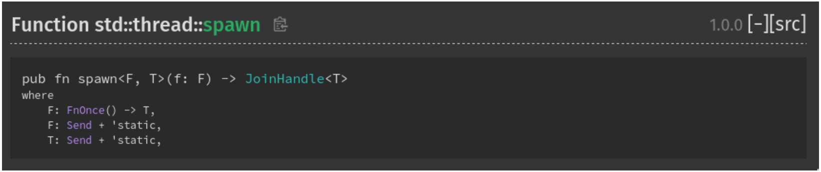
```
$ cargo run --example 06_thread_counter
   Compiling rust-demo v0.1.0 (/home/marcel/Documents/dev/projects/rust-presentation/rust-demo)
error[E0499]: cannot borrow `counter` as mutable more than once at a time
  --> examples/06_thread_counter.rs:8:36
   |
8  |           let handle = thread::spawn(|| {
   |                        -             ^^ `counter` was mutably borrowed here in the previous iteration of the loop
   |  ______________________|
   | |
9  | |             for _ in 0..100_000 {
10 | |                 counter += 1;
   | |                 ------- borrows occur due to use of `counter` in closure
11 | |             }
12 | |         });
   | |__________- argument requires that `counter` is borrowed for `'static`

error[E0373]: closure may outlive the current function, but it borrows `counter`, which is owned by the current function
  --> examples/06_thread_counter.rs:8:36
   |
8  |         let handle = thread::spawn(|| {
   |                                    ^^ may outlive borrowed value `counter`
9  |             for _ in 0..100_000 {
10 |                 counter += 1;
   |                 ------- `counter` is borrowed here
   |
note: function requires argument type to outlive `'static`
  --> examples/06_thread_counter.rs:8:22
   |
8  |           let handle = thread::spawn(|| {
   |  ______________________^
9  | |             for _ in 0..100_000 {
10 | |                 counter += 1;
11 | |             }
12 | |         });
   | |__________^
help: to force the closure to take ownership of `counter` (and any other referenced variables), use the `move` keyword
   |
8  |         let handle = thread::spawn(move || {
   |                                    ++++
```

First problem: thread can outlive the counter

“But we join the thread before exiting from main, so this code should be valid!”

That’s right, `counter` can’t go out of scope before threads finish. Why the error then?



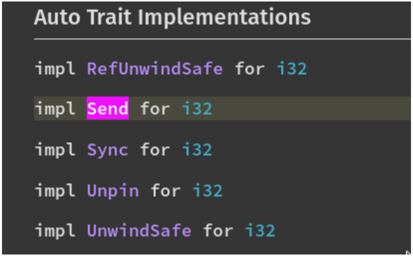
Function std::thread::spawn 1.0.0 [−][src]

```
pub fn spawn<F, T>(f: F) -> JoinHandle<T>
where
    F: FnOnce() -> T,
    F: Send + 'static,
    T: Send + 'static,
```

Figure 2: https://doc.rust-lang.org/stable/std/thread/fn.spawn.html

`F: Send + 'static` means that variables borrowed by `F` have to be `Send` and `'static`.

- `Send`: Need to be able to send stuff to the thread. Pretty self explanatory. Is `i32: Send`?



Auto Trait Implementations

```
impl RefUnwindSafe for i32
impl Send for i32
impl Sync for i32
impl Unpin for i32
impl UnwindSafe for i32
```

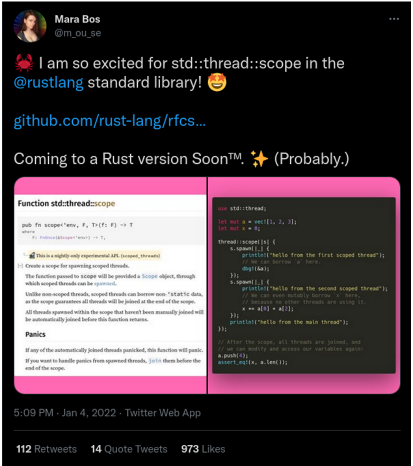
Figure 3: https://doc.rust-lang.org/stable/std/primitive.i32.html#impl-Send

You bet.

- 'static: Data has to have 'static lifetime, which is to say, it needs to live for the entire duration of the program

  In theory it shouldn't be necessary. There are ways to spawn the thread which do not require this. The crossbeam crate provides the scoped thread spawning function.

  Also, scoped threads will be added to standard library in the future:



Mara Bos
@m_ou_se

🦀 I am so excited for std::thread::scope in the @rustlang standard library! 🤩

github.com/rust-lang/rfcs...

Coming to a Rust version Soon™. ✨ (Probably.)

Function std::thread::scope

```
pub fn scope<'env, F, T>(f: F) -> T
where
    F: FnOnce(&Scope<'env>) -> T,
```

This is a nightly-only experimental API. (scoped_threads)

[-] Create a scope for spawning scoped threads.

The function passed to scope will be provided a Scope object, through which scoped threads can be spawned.

Unlike non-scoped threads, scoped threads can borrow non-'static data, as the scope guarantees all threads will be joined at the end of the scope.

All threads spawned within the scope that haven't been manually joined will be automatically joined before this function returns.

Panics

If any of the automatically joined threads panicked, this function will panic.

If you want to handle panics from spawned threads, join them before the end of the scope.

```
use std::thread;

let mut a = vec![1, 2, 3];
let mut x = 0;

thread::scope(|s| {
    s.spawn(|_| {
        println!("hello from the first scoped thread");
        // We can borrow `a` here.
        dbg!(&a);
    });
    s.spawn(|_| {
        println!("hello from the second scoped thread");
        // We can even mutably borrow `x` here,
        // because no other threads are using it.
        x += a[0] + a[2];
    });
    println!("hello from the main thread");
});

// After the scope, all threads are joined, and
// we can modify and access our variables again:
a.push(4);
assert_eq!(x, a.len());
```

5:09 PM · Jan 4, 2022 · Twitter Web App

112 Retweets 14 Quote Tweets 973 Likes

For now, we will just make counter a static:

```
static mut COUNTER: i32 = 0;

fn main() {
    // ...
}
```

```
$ cargo run --example 06_thread_counter
   Compiling rust-demo v0.1.0 (/home/marcel/Documents/dev/projects/rust-presentation/rust-demo)
error[E0133]: use of mutable static is unsafe and requires unsafe function or block
  --> examples/06_thread_counter.rs:11:17
   |
11 |                 COUNTER += 1;
   |                 ^^^^^^^^^^^^ use of mutable static
   |
   = note: mutable statics can be mutated by multiple threads: aliasing violations or data races will cause undefined behavior

For more information about this error, try `rustc --explain E0133`.
error: could not compile `rust-demo` due to previous error
```

The cursed fix: add unsafe:

```
let handle = thread::spawn(|| {
fn main() {
    // ...

    for _ in 0..100_000 {
        unsafe {
            COUNTER += 1;
        }
    }

    // ...

    unsafe {
        println!("{COUNTER}");
    }
}
```

```
$ cargo run --example 06_thread_counter
    Finished dev [unoptimized + debuginfo] target(s) in 0.00s
     Running `target/debug/examples/06_thread_counter`
354443
```

The usual ensues. . .

Now make it good.

We will sync access to the counter with a Mutex.

```
use std::{sync::Mutex, thread};

static COUNTER: Mutex<i32> = Mutex::new(0);

fn main() {
    let mut handles = Vec::new();

    for _ in 0..4 {
        let handle = thread::spawn(|| {
            for _ in 0..100_000 {
                let mut guard = COUNTER.lock().unwrap();
                *guard += 1;
            }
        });
        handles.push(handle);
    }

    // join threads before exiting the main function.
    for handle in handles {
        handle.join().unwrap();
    }

    let counter = COUNTER.lock().unwrap();
    println!("{counter}");
}
```

Output:

```
$ cargo run --example 06_thread_counter
   Compiling rust-demo v0.1.0 (/home/marcel/Documents/dev/projects/rust-presentation/rust-demo)
error[E0015]: calls in statics are limited to constant functions, tuple structs and tuple variants
 --> examples/06_thread_counter.rs:3:30
  |
3 | static COUNTER: Mutex<i32> = Mutex::new(0);
  |                              ^^^^^^^^^^^^^

For more information about this error, try `rustc --explain E0015`.
error: could not compile `rust-demo` due to previous error
```

Rust disallows running functions for static variables.

Solution: use reference counting for shared ownership.

```rust
use std::{
    sync::{Arc, Mutex},
    thread,
};

fn main() {
    // wrap the mutex in an Atomic Reference Counter
    let counter: Arc<Mutex<i32>> = Arc::new(Mutex::new(0));
    let mut handles = Vec::new();

    for _ in 0..4 {
        // clone the reference counter. Clone is &T -> T, so now we can move
        // the refcounter inside the closure
        let c = Arc::clone(&counter);
        let handle = thread::spawn(move || {
            for _ in 0..100_000 {
                let mut guard = c.lock().unwrap();
                *guard += 1;
            }
        });
        handles.push(handle);
    }

    // join threads before exiting the main function.
    for handle in handles {
        handle.join().unwrap();
    }

    let counter = counter.lock().unwrap();
    println!("{counter}");
}
```

Output:

```
$ cargo run --example 06_thread_counter
   Compiling rust-demo v0.1.0 (/home/marcel/Documents/dev/projects/rust-presentation/rust-demo)
    Finished dev [unoptimized + debuginfo] target(s) in 0.20s
     Running `target/debug/examples/06_thread_counter`
400000
```

This is correct!

For scoped threads and comparisons to Go, see Some mistakes Rust doesn't catch

Subsection 3

Async

Subsection 4

Other good sources

Other good sources

- I am a Java, C#, C or C++ developer, time to do some Rust

  Comprehensive introduction to Rust for developers of other Object Oriented languages
- Declarative memory management

  How Rust memory management differs from C or C++
- Learn Rust in Y minutes
- Rust Book

Section 4

Other tips

Other tips

- Use clone
- Use clippy

Section 5

Sources

Sources

- https://fasterthanli.me
- https://www.youtube.com/c/fasterthanlime
- https://www.youtube.com/c/JonGjengset
- https://pkolaczk.github.io
- https://www.reddit.com/r/rustjerk

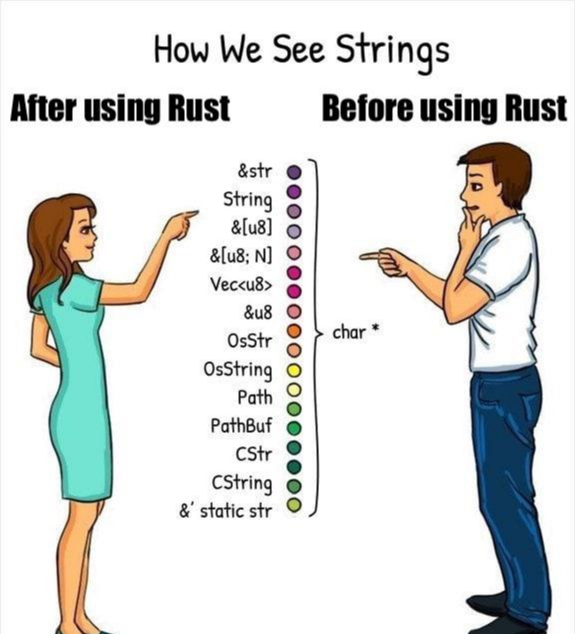
Section 6

Bonus

Subsection 1

Owned vs borrowed types

Owned vs borrowed types



How to make sense of this?

It’s a common pattern that types in Rust are divided into “owned” types and “borrowed” types.

Owned types:

- `String` - Owned, Rust native, UTF-8 encoded, explicitly sized string
- `CString` - Owned C-compatible null-terminated string
- `OsString` - Owned, platform-native strings (so on Unix UTF-8, on Windows UTF-16, etc.)
- `PathBuf` - Wrapper around `OsString`, with logic to manage path according to the platform (so on Unix separator is /, on Windows it's \, etc.)
- `Vec<u8>` - Owned vector of unsigned bytes

Borrowed types:

- `&str`
- `&' static str`
- `CStr`
- `OsStr`
- `Path`
- `&[u8]`
- `&[u8; N]`
- `&u8`

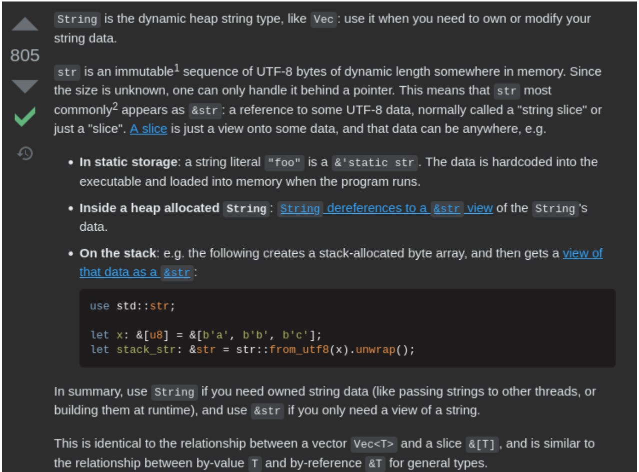
“But you told me borrowing in Rust is done with `&`, so why do some don’t have that? Also, if to borrow we just add `&`, then why is borrowed string not just `&String`? What’s the difference?”

Strings

To show the difference we'll look into just `&str` and `String`.

First, like any respectable programmer, let's turn for help to Stack Overflow:

https://stackoverflow.com/questions/24158114/what-are-the-differences-between-rusts-string-and-str



`String` is the dynamic heap string type, like `Vec`: use it when you need to own or modify your string data.

`str` is an immutable[1] sequence of UTF-8 bytes of dynamic length somewhere in memory. Since the size is unknown, one can only handle it behind a pointer. This means that `str` most commonly[2] appears as `&str`: a reference to some UTF-8 data, normally called a "string slice" or just a "slice". A slice is just a view onto some data, and that data can be anywhere, e.g.

- **In static storage**: a string literal `"foo"` is a `&'static str`. The data is hardcoded into the executable and loaded into memory when the program runs.
- **Inside a heap allocated `String`**: `String` dereferences to a `&str` view of the `String`'s data.
- **On the stack**: e.g. the following creates a stack-allocated byte array, and then gets a view of that data as a `&str`:

```rust
use std::str;

let x: &[u8] = &[b'a', b'b', b'c'];
let stack_str: &str = str::from_utf8(x).unwrap();
```

In summary, use `String` if you need owned string data (like passing strings to other threads, or building them at runtime), and use `&str` if you only need a view of a string.

This is identical to the relationship between a vector `Vec<T>` and a slice `&[T]`, and is similar to the relationship between by-value `T` and by-reference `&T` for general types.

`String`:

- Mutable
- Manages memory
- Heap-allocated

`&str`:

- Immutable, “view” of the string
- A reference to memory managed by somebody else - Is a “slice” so it can point to any portion of the string
- Can be on heap, on stack, static, etc.

How they look on the inside?

In *Rust pseudo-code*:

String:

```
struct String {
    data: *mut u8,      // pointer to heap allocated data - 8 bytes
    length: usize,      // length of the string - 8 bytes
    capacity: usize,    // capacity of the string to grow, size of the current allocation - 8 bytes
}

dbg!(std::size_of::<String>()); // 24
```

Str:

```
struct &str {
    data: *const u8 // pointer to string - 8 bytes
    length: usize   // length of the string - 8 bytes
}

dbg!(std::mem::size_of::<&str>()); // 16
```

So internally they're quite different, `&str` is smaller, and they do different things, that's why they are different types. The same goes for the rest of types.

The following are analogous to `String` and `&str`:

- `CString` and `CStr`
- `OsString` and `OsStr`
- `PathBuf` and `Path`

More about strings: https://fasterthanli.me/articles/working-with-strings-in-rust

Vecs and slices

What about `Vec<u8>`, `[u8; N]`, `&[u8; N]`, `&[u8]`?

`Vec<u8>` and `[u8; N]` are arrays of `u8`; former is growable and heap-allocated, latter is constant size and may be on the stack.

`&[u8; N]` - a reference to array of type `u8` of size `N`

`&[u8]` - a slice of type `u8` (so, a “view” into an array of type `u8`, either `Vec<u8>` or `[u8; N]`)

“Ok, what does that mean for me, which should i use?”

In methods, use least restricive, most “generic” type:

Instead of:

```
fn read_bytes(bytes: &Vec<u8>)
fn read_string(text: &String)
```

do:

```
fn read_bytes(bytes: &[u8])
fn read_string(text: &str)
```

But dont overthink it for now:

```rust
fn foo(input: Vec<Data>) {
    // ...
}
```

```rust
fn foo(input: impl Iterator<Item = Data>) {
    // ...
}
```

```rust
fn foo(input: impl IntoIterator<Item = Result<Data, Error>>) {
    // ...
}
```

```rust
fn foo(
    input: Either<
        Either<
            impl IntoIterator<Item = std::result::Result<Data, Error>>,
            BoxFuture<'_, impl IntoIterator<Item = std::result::Result<Data, Error>>>,
        >,
        BoxStream<'_, std::result::Result<Data, Error>>,
    >,
) {
    // ...
}
```