Rust Presentation

Marcel Guzik

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	
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

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

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)

```rust
#[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 `Resul
  |               |
  |               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")`.

```
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, mess
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

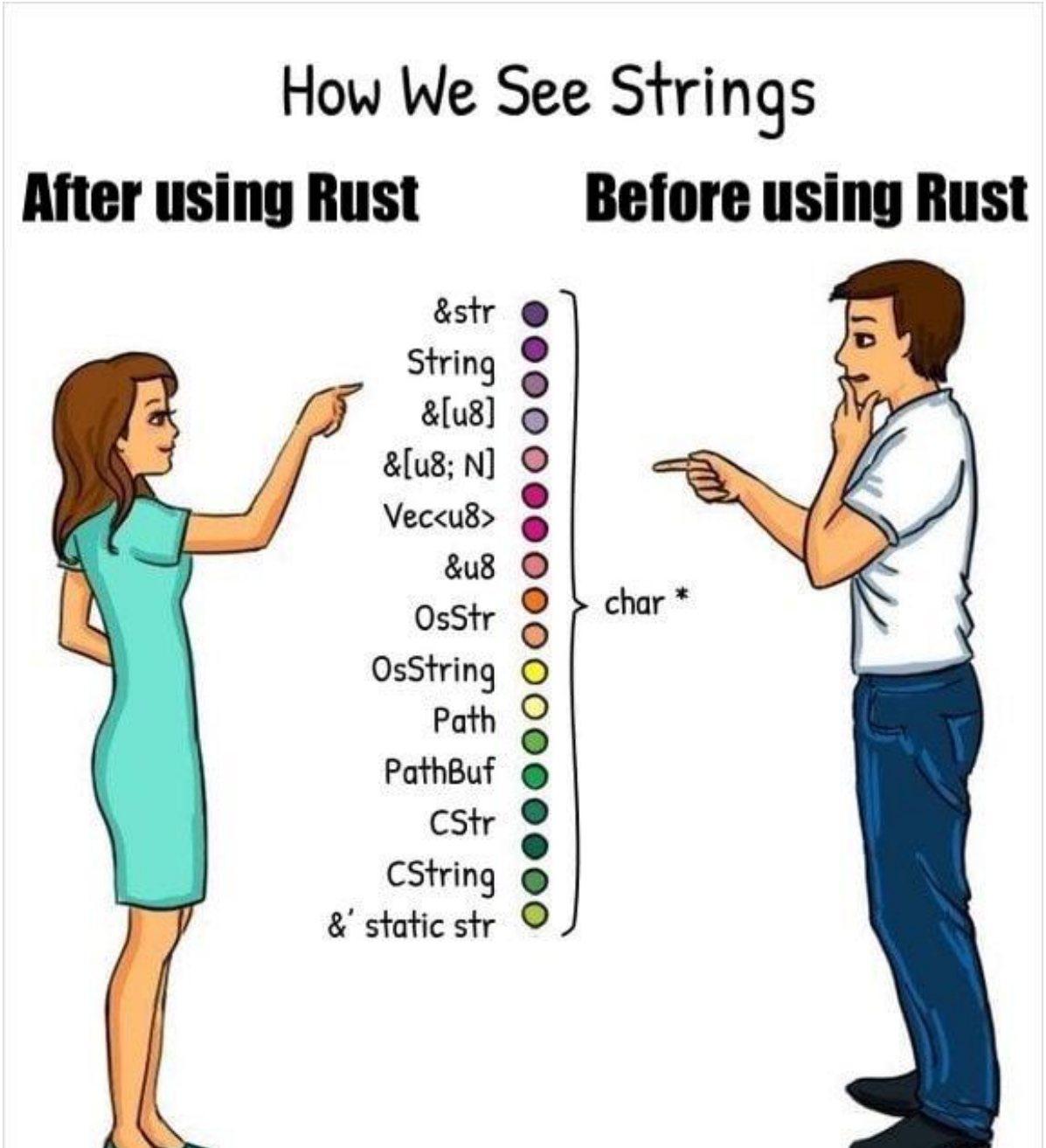
That's why Rust doesn't have null.

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

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

805

`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`:

```
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:

Subsection 7

Big stdlib

Big stdlib

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.

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

Sharing data between different threads

Subsection 3

Crates

Crates

Crates

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