WEBINAR

Moving from C++ to Rust

Craig Cuthbert | August 24, 2023

About ICS

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- Full stack software development
- Cloud-native application development
- Medical regulatory compliance
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Agenda

- What is Rust?
- Discuss similarities and differences between C++ and Rust at a high level
- Look at common pain points in switching to Rust.
- Rust Pros and Cons
- Who is using Rust?
- Why would we want to use Rust vs C++?
- Language Features
- Cargo Build System
- Code Examples
- Future Directions
- Summary and Conclusions
- References

Introduction

Why would we want to use Rust vs C++?

Safety!

Speed Comparable to C/C++

Modern Language with Modern Tools

Fun!!

What is Rust?

- A big reason Rust was invented was to address some shortcomings of C and C++ while keeping similar performance.
- Multi-paradigm programming language designed for performance and safety.
- Although syntactically similar to C++ in some cases, it is an entirely different language with a steep learning curve.
- Can guarantee memory safety by using a “borrow checker” to validate references. In other words, null references are caught a compile time, not run time.
- Fully compiled, no runtime, comparable performance to C++.
- Does not use garbage collection; reference counting is optional.
- Originally developed by Mozilla research, now run by an independent non-profit foundation.

Pros of using Rust

- Modern Language with modern tools.
- Safety, Concurrency, Speed.
- Reduce or eliminate memory issues without sacrificing performance.
- Developer community likes it and it is growing in popularity.
- Open source libraries and adoption continues to grow.
- Eliminates complex C++ build scripts using the Cargo build system and package manager.
- Concurrency can be trivial compared to C++
- More errors are caught at compile time than in C++.
- The compiler will produce detailed error reports of any errors and warnings.
- Very good documentation.
- Testing, deployment and documentation are built into the language tools and not an “afterthought”

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Cons of using Rust

- Steep learning curve.
- First step is to get the thing to compile!
- Need to approach Rust programming differently. Porting may not be straightforward (e.g if porting inheritance, it will need to be refactored using traits).
- Slower compile times.
- There are currently no mature GUI frameworks for Rust such as Qt.
- Qt can be used but requires unsafe code and/or generated bridge code. It may not be the best fit at the moment.
- Crossing boundaries (e.g. C++ to Rust or the reverse) can be difficult.

Who is using Rust?

- Mozilla https://www.techrepublic.com/article/rust-not-firefox-is-mozillas-greatest-industry-contribution/
- Dropbox https://www.wired.com/2016/03/epic-story-dropboxs-exodus-amazon-cloud-empire/
- Figma https://www.figma.com/blog/rust-in-production-at-figma/
- Facebook https://engineering.fb.com/2021/04/29/developer-tools/rust/
- Discord https://github.com/serenity-rs/serenity
- Amazon https://aws.amazon.com/blogs/opensource/sustainability-with-rust/
- Microsoft https://learn.microsoft.com/en-us/windows/dev-environment/rust/rust-for-windows
- Cloudflare https://blog.cloudflare.com/introducing-oxy/




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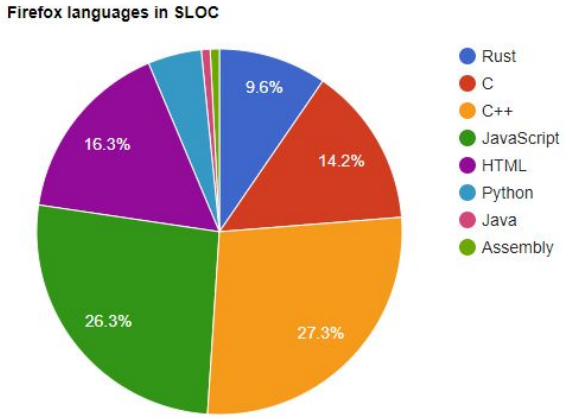
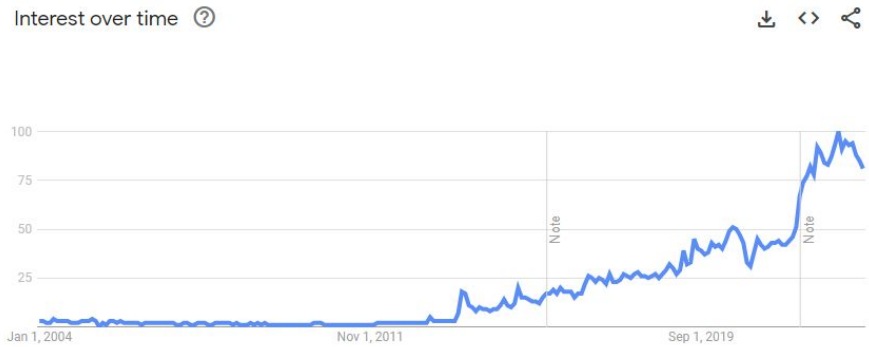
How much Rust is in Firefox?

Rust was invented by Mozilla for the Firefox browser to deal with the classic issues in C++. Since its inception, interest has been steadily climbing…





Language Features

Some similarities to C++:

- Data structures are similar to C++ structs.
- Control structures such as if, else, for, while are similar to C++ although the syntax is slightly different (e.g. no brackets around the condition).
- Enums are more powerful and can contain variant data values and methods.
- Break and Continue are similar to C++.
- Arrays, Hash Maps, Iterators etc. have similar function, but also differences.
- Has Lambda functions (closures).
- As in C++ we can create macros, but the syntax is strange (dev complaints).
- Data types can be declared explicitly or can be inferred by the compiler similar to the C++ auto keyword.

Simple Code Example

```
// Hello world plus factorial and for loop
fn factorial(i: u64) -> u64 {
    match i {
        0 => 1,
        n => n * factorial(n - 1),
    }
}
fn main() {
    println!("Hello, World!");
    for i in 0..20 {
       println!("factorial({}) = {}", i, factorial(i));
    }
}
```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CODE DEMO

SIMPLE EXAMPLE

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Cargo Build System

- Tool to help manage Rust projects.
- Manages building code, downloading dependencies the code needs, and building those dependencies (and more)
- Conceptually similar to qmake or cmake (but doesn't generate make files).

In the simplest case, Cargo.toml just contains:

```
[package]
name = "hello_world"
version = "0.0.1"
authors = [ "Linus Torvalds <ltorvalds@linuxfoundation.org>" ]
```

Usually source code is in a src subdirectory, e.g. src/main.rs

Cargo Build System

```
% cargo build
   Compiling simple_example v0.0.1
(C:\Source\Rust\webinar\simple_example)
    Finished dev [unoptimized + debuginfo] target(s) in 0.26s

% cargo run
    Finished dev [unoptimized + debuginfo] target(s) in 0.02s
     Running `target\debug\simple_example.exe`
Hello, World!
```

Trivia: Rust programmers refer to themselves as "Rustaceans".

CODE DEMO

HELLO WORLD

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Language Features

Differences from C++ - Ownership and Memory Management:

- An ownership system where all values have a unique owner, and the scope of the value is the same as the scope of the owner.
- Since there is only one owner, any reference is tied to the lifetime of the owner. If this is ambiguous the compiler will error.
- Lifetimes are tied to code blocks unless the lifetime is explicitly set by the developer. In other words, if a lifetime is ambiguous, the program will not compile.
- The Rust compiler enforces these rules at compile time and also checks that all references are valid. Dangling/null pointers are thus eliminated.
- Memory and other resources are managed through the resource acquisition is initialization (RAII) convention, with optional reference counting using a “Reference Counted Smart Pointer” or Rc<T>.

Language Features

Ownership and Memory Management:

- Type declaration for variables declared with the keyword let.
- Values can be passed by immutable reference, by mutable reference, or by value. Variables default to immutable. Can add ‘mut’ keyword to change.
- At all times, there can either be multiple immutable references or one mutable reference (an implicit readers-writer lock).
- Race and deadlock conditions are limited by compile time restrictions.
- Does not use an automated garbage collection system, but also does not require explicit deletion of pointers.
- “unsafe” code which can subvert some of these restrictions may be written using the language's unsafe keyword.

Language Features

Ownership:

- Using a (non primitive type such as a string) variable directly with another variable or when passed to a function transfers the ownership. The previous variable is dropped (in this case the stack pointer s1 will be removed)

```
let s1 = String::from("abc");
let s2 = s1; // causes a "move" and s1 is now invalid
println!("s1: {}, s2: {}", s1, s2); // compile error
```

When s2 variable eventually goes out of scope at the end of this function, the s2 stack variable will be removed along with the "abc" heap allocation automatically.

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Language Features

Ownership:

```
let s1 = String::from("abc");
let s2 = &s1; // "borrow" a reference
println!("s1: {}, s2: {}", s1, s2); // ok

let s1 = String::from("abc");
let s2 = s1.clone(); // deep copy
println!("s1: {}, s2: {}", s1, s2); // ok
```

CODE DEMO

LIFETIMES

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Language Features

Types and Polymorphism:

- Composition is favored over inheritance.
- No inheritance of types, but inheritance of “Traits”.
- Polymorphism is done using traits (similar to an interface) .
- Functions can be given generic parameters, which usually require the generic type to implement a certain trait or traits.
- Object system is based around implementations, traits and structured types.

CODE DEMO

OBJECT EXAMPLE

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Language Features

Language Extensions:

- Possible to extend the Rust language using the procedural macro mechanism.
- The println! macro is an example of a function-like macro.

Trivia: Rust has been voted the "most loved programming language" in the Stack Overflow Developer Survey every year since 2016.

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Future Directions

- Linux has recently added support for Kernel development using Rust.
- Microsoft has created Rust for Windows, which allows creating Rust apps for Windows with bindings for WIN32 APIs.
- The Google Android team writing low level Android code in Rust.
- Facebook is using Rust in all aspects of development with hundreds of developers writing millions of lines of Rust code.
- Support for embedded platforms (including microcontrollers).
- Ability to compile to WebAssembly to run in a browser.

Fun fact: A 2021 survey of programmers by SlashData reported that Rust and Lua were the two fastest growing programming language communities in the past 12 months.

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Summary and Conclusions

Two Linux security researchers estimate that about two-thirds of Linux kernel vulnerabilities come from memory safety issues. One Microsoft security expert estimates that 70% of the CVEs originating at Microsoft are memory safety issues. Rust, in theory, can avoid these with its inherently safer memory model.

Rust is a possible replacement for C++ on multiple platforms. Mostly driven by memory safety and the fact that it is more modern than C++. Comparable in performance and platform support and controlled by an independent foundation https://foundation.rust-lang.org/.

To get started visit https://rustup.rs/ and follow the instructions. I recommend using https://code.visualstudio.com/docs/languages/rust as the editor which has very good support for Rust.

Resources to learn more about Rust

- https://www.rust-lang.org/
- https://doc.rust-lang.org/book/title-page.html
- https://doc.rust-lang.org/stable/rust-by-example/
- https://crates.io/
- Online training sites such as Udemy and Pluralsight
  - https://www.udemy.com/course/ultimate-rust-crash-course/
  - https://www.udemy.com/course/ultimate-rust-2/
  - https://www.udemy.com/course/rust-fundamentals/
  - https://www.udemy.com/course/rust-programming-master-class-from-beginner-to-expert
  - https://www.pluralsight.com/courses/fundamentals-rust

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Other References

Some helpful references

- https://doc.rust-lang.org/std/
- https://rust-lang.github.io/rust-clippy/master/index.html
- https://cheats.rs
- https://www.kernel.org/doc/html/latest/rust/index.html
- https://docs.microsoft.com/en-us/windows/dev-environment/rust/rust-for-windows
- https://github.com/rust-unofficial/awesome-rust#applications
- https://gist.github.com/zbraniecki/b251714d77ffebbc73c03447f2b2c69f
- https://www.zdnet.com/article/linus-torvalds-on-where-rust-will-fit-into-linux
- https://slint.dev/
- https://github.com/KDE/rust-qt-binding-generator

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QUESTIONS?

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