accu
2022

A FRIENDLY INTRODUCTION TO RUST FOR C++ DEVELOPERS

HENDRIK NIEMEYER

A Friendly Introduction to Rust For C++ Developers

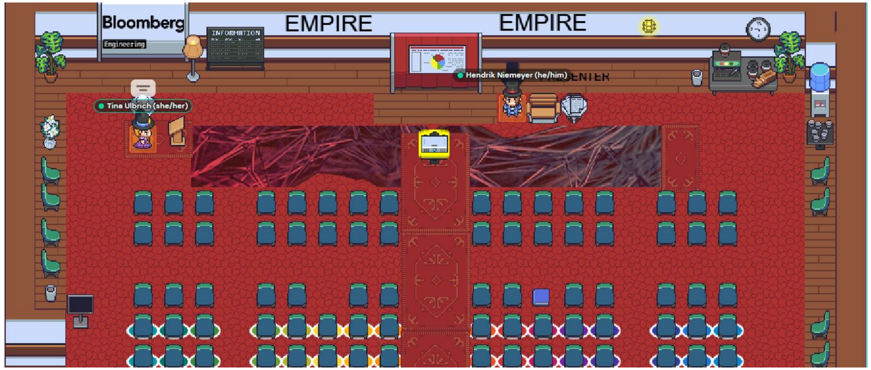
Hendrik Niemeyer (he/him)

Link to Slides:

https://tinyurl.com/y6exty57

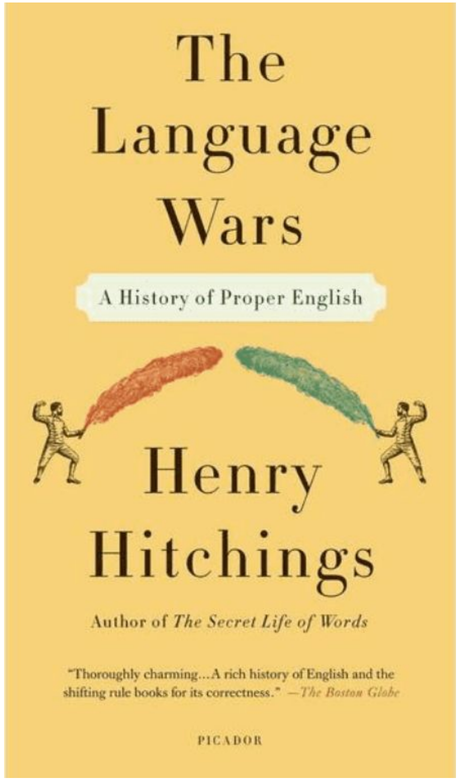
Feedback and Questions

- Twitter: @hniemeye
- LinkedIn: hniemeyer87
- GitHub: hniemeyer



Ask questions in Q&A section of zoom now or later in the gathertown room.

Disclaimer


The Language Wars

A History of Proper English

Henry Hitchings

Author of *The Secret Life of Words*

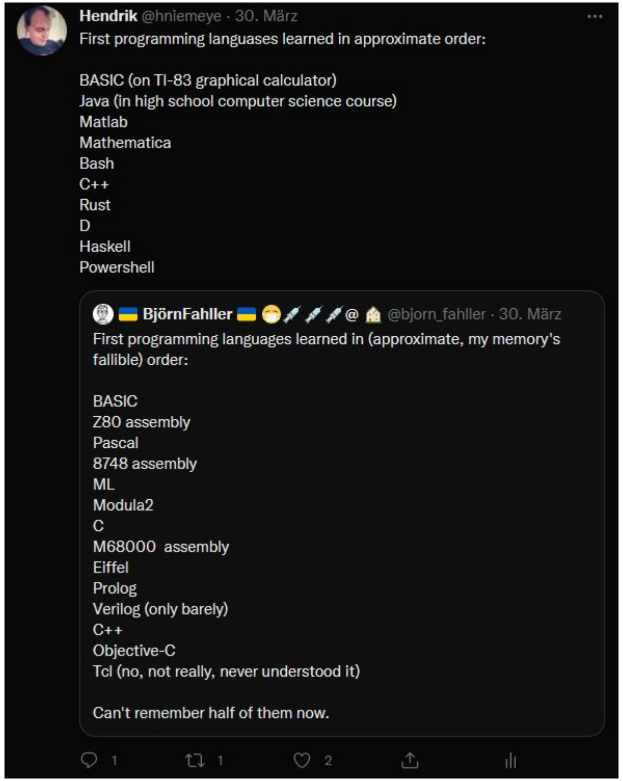
"Thoroughly charming…A rich history of English and the shifting rule books for its correctness." —*The Boston Globe*

PICADOR

If You Want to Try Out Code

- Compiler Explorer supports Rust
- Rust Playgound
- Install Rust

Motivation



Hendrik @hniemeye · 30. März

First programming languases learned in approximate order:

BASIC (on TI-83 graphical calculator)
Java (in high school computer science course)
Matlab
Mathematica
Bash
C++
Rust
D
Haskell
Powershell

🇺🇦 **BjörnFahller** 🇺🇦 😷💉💉💉@ 🏡 @bjorn_fahller · 30. März

First programming languages learned in (approximate, my memory's fallible) order:

BASIC
Z80 assembly
Pascal
8748 assembly
ML
Modula2
C
M68000 assembly
Eiffel
Prolog
Verilog (only barely)
C++
Objective-C
Tcl (no, not really, never understood it)

Can't remember half of them now.

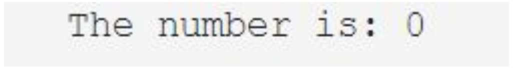
1 1 2

Motivation: Tooling

- Setting up a new project should be easy
- (de facto) standard build system, package manager, testing framework and static analyzer makes life easier
- C++ has many, very good tools for these tasks
- Rust has cargo and crates.io

Motivation: Safety

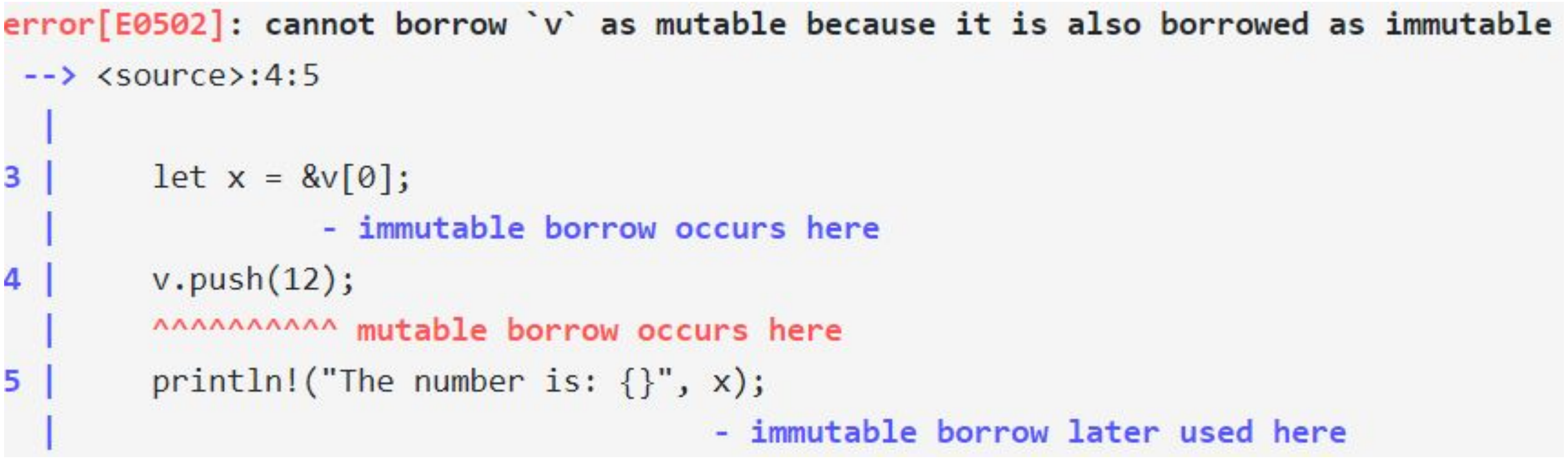
```cpp
int main()
{
    std::vector<int> v({-7,1,2,3});
    int& x = v[0];
    v.push_back(12);
    std::cout << "The number is: " << x;
}
```



```
The number is: 0
```

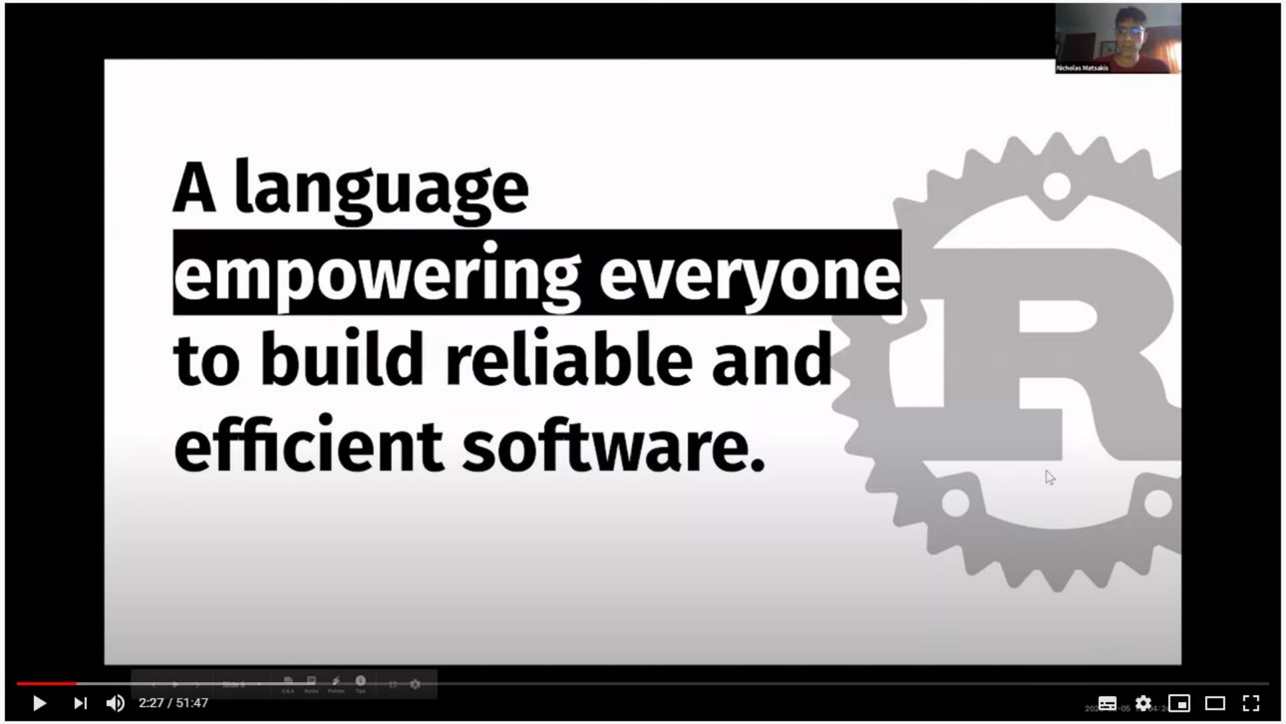
https://gcc.godbolt.org/z/8Mao4T

Motivation: Safety



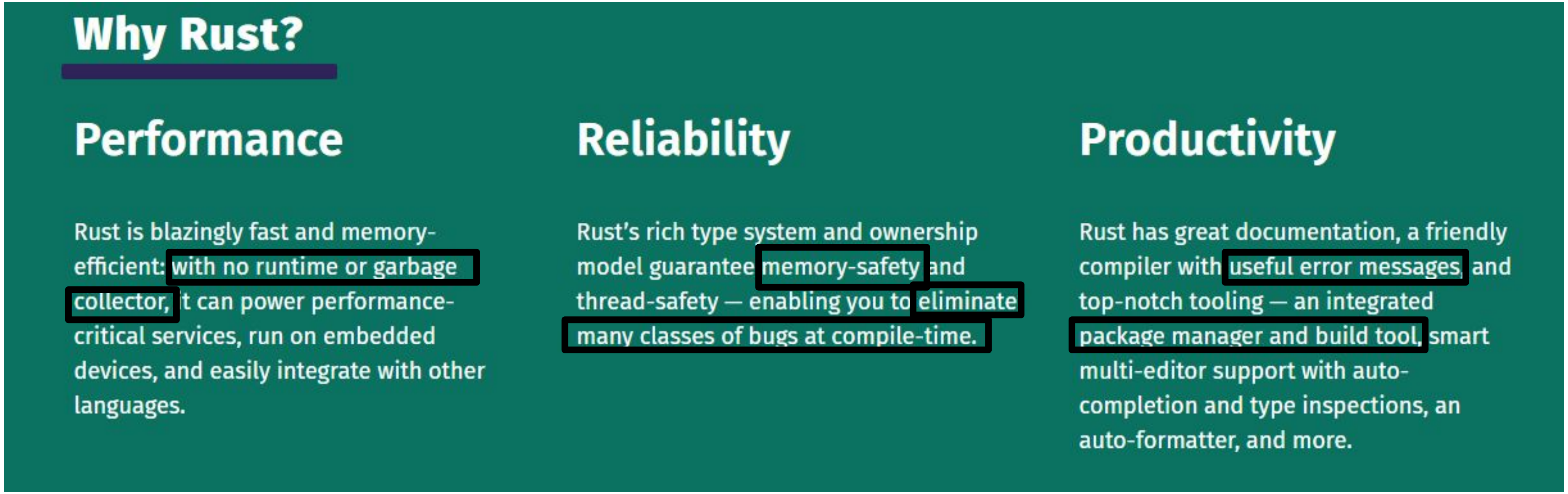
```
error[E0502]: cannot borrow `v` as mutable because it is also borrowed as immutable
 --> <source>:4:5
  |
3 |     let x = &v[0];
  |              - immutable borrow occurs here
4 |     v.push(12);
  |     ^^^^^^^^^^ mutable borrow occurs here
5 |     println!("The number is: {}", x);
  |                                   - immutable borrow later used here
```

Motivation


A language
empowering everyone
to build reliable and
efficient software.

RustConf 2020 - Opening Keynote

What Is Rust?



Why Rust?

Performance

Rust is blazingly fast and memory-efficient: with no runtime or garbage collector, it can power performance-critical services, run on embedded devices, and easily integrate with other languages.

Reliability

Rust's rich type system and ownership model guarantee memory-safety and thread-safety — enabling you to eliminate many classes of bugs at compile-time.

Productivity

Rust has great documentation, a friendly compiler with useful error messages, and top-notch tooling — an integrated package manager and build tool, smart multi-editor support with auto-completion and type inspections, an auto-formatter, and more.

Rust at ACCU 2022

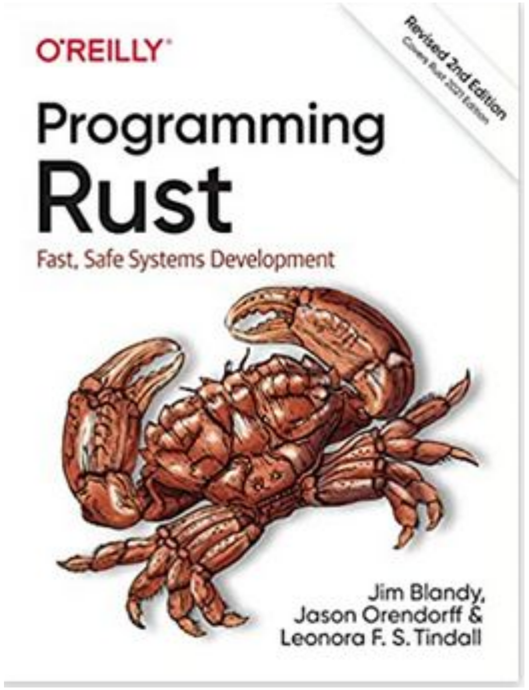
Coroutines: C++ vs Rust: 11:00 - 12:30 Friday 8th April 2022 BST

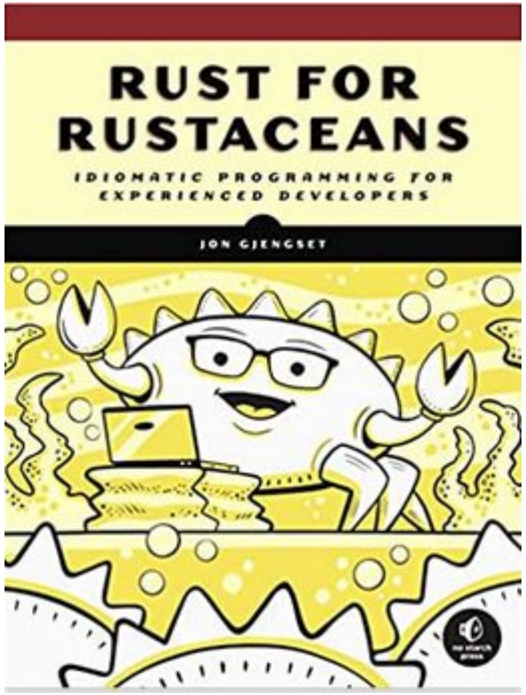
Neotron – writing a single-tasking ‘DOS’ for Arm microcontrollers, in Rust: 14:00 - 15:30 Friday 8th April 2022 BST

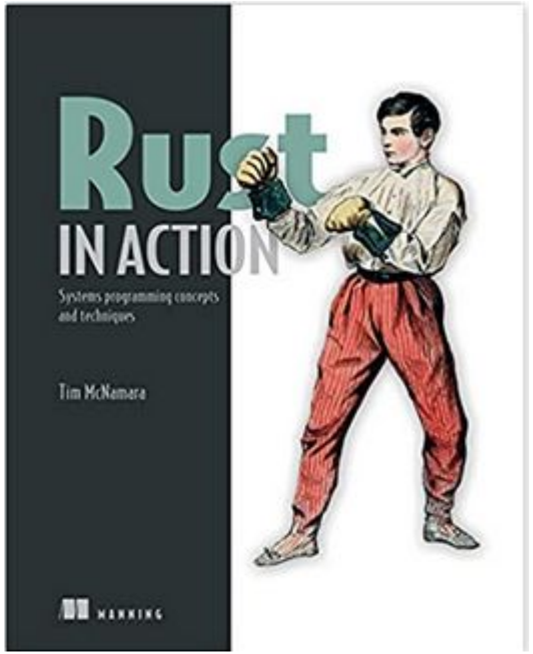
Free Resources to Learn Rust

- Rust Book
- Rust Cookbook
- Rust by Example
- ferrous systems - teaching material
- https://jrvidal.github.io/explaine.rs/

Paid Resources to Learn Rust


O'REILLY
Revised 2nd Edition
Covers Rust 2021 Edition
Programming Rust
Fast, Safe Systems Development
Jim Blandy, Jason Orendorff & Leonora F. S. Tindall





Syntax and Mutability

```
fn add(x: i32, y: i32) -> i32
{ x+y }

fn main() {
    let a = 5;
    let b = 10;
    let mut res = add(a,b);
    res += 5;
    println!("The result is
{}", res);
}
```

```
int add(int x, int y)
{ return x + y; }

int main() {
  const auto a = 5;
  const auto b = 10;
  auto res = add(a, b);
  res += 5;
  std::cout << "The result is
" << res;
}
```

const in Rust

```rust
const fn fib(n: i32) -> i32 {
    if n < 2 { 1 }
    else { fib(n-1) + fib(n-2) }
}

fn main() {
    let x = fib(5);
    const S: i32 = fib(8);
    println!("{}", x);
    println!("{}", S);
}
```

```cpp
constexpr int fib(int n) {
  if (n < 2)
    return 1;
  else
    return fib(n - 1) + fib(n - 2);
}

int main() {
  const auto x = fib(5);
  constexpr auto S = fib(8);
  std::cout << x << '\n';
  std::cout << S << '\n';
}
```

Variables and References

- Each value in Rust has a variable that’s called its owner
- There can only be one owner at a time
- When the owner goes out of scope, the value will be dropped
- At any given time, you can have either one mutable reference or any number of immutable references but not both
- References must always be valid

References

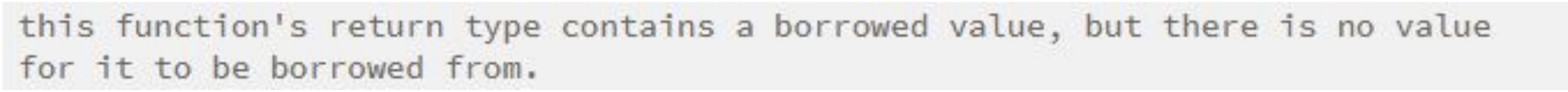
```rust
let mut s = String::from("hello");

let r1 = &s; // no problem
let r2 = &s; // no problem
let r3 = &mut s; // BIG PROBLEM

println!("{}, {}, and {}", r1, r2, r3);
```

References

```rust
let mut s = String::from("hello");

let r1 = &s; // no problem
let r2 = &s; // no problem
println!("{} and {}", r1, r2);
// r1 and r2 are no longer used after this point

let r3 = &mut s; // no problem
println!("{}", r3);
```

Dangling References

```rust
fn main() {
    let reference_to_nothing = dangle();
}

fn dangle() -> &String {
    let s = String::from("hello");

    &s
}
```



```
this function's return type contains a borrowed value, but there is no value
for it to be borrowed from.
```

Lifetimes

- Lifetimes describe the duration a value remains in memory (compared to other values)
- They are descriptive types which the compiler usually can infer itself
- used by compiler to reason about memory safety of code

Rust Playground

https://gcc.godbolt.org/z/vdTMzzWaP

Are there any questions?

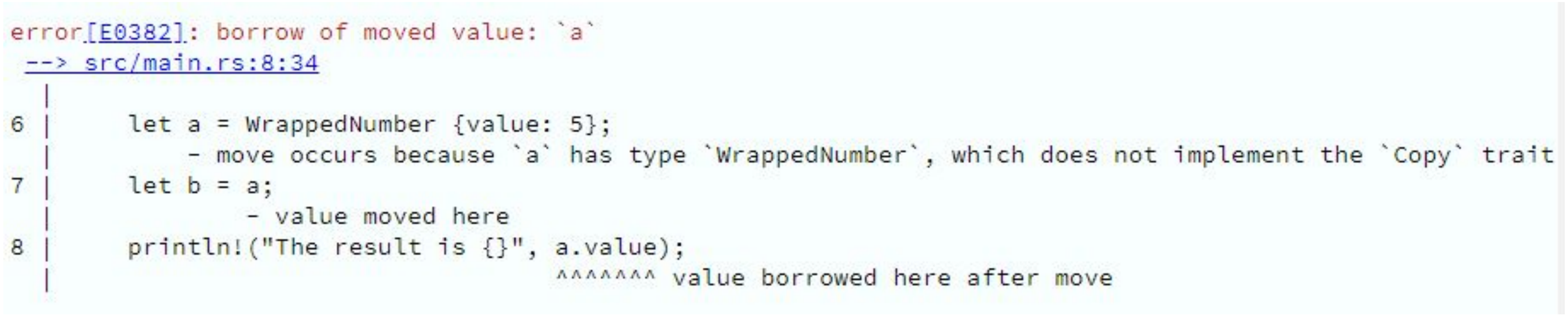
Copy Semantics

```rust
fn main() {
    let a = 5;
    let b = a;
    println!("The result is {}", a);
}
```

Move Semantics

```rust
struct WrappedNumber {
    value: i32
}

fn main() {
    let a = WrappedNumber {value: 5};
    let b = a;
    println!("The result is {}", a.value);
}
```

Move Semantics



```
error[E0382]: borrow of moved value: `a`
 --> src/main.rs:8:34
  |
6 |     let a = WrappedNumber {value: 5};
  |         - move occurs because `a` has type `WrappedNumber`, which does not implement the `Copy` trait
7 |     let b = a;
  |             - value moved here
8 |     println!("The result is {}", a.value);
  |                                  ^^^^^^^ value borrowed here after move
  |
```

Expressions

```
fn main() {
    let x = 12;
    let number = if x < 11 { 5 } else { 6 };
    let mut counter = 0;
    let result = loop {
        counter += number;
        if counter> 3*x {
            break counter * x;
        }
    };
    println!("The value of number is: {}", number);
    println!("The value of result is {}", result);
}
```

Are there any questions?

Structs

```rust
struct Square {
    length: f32
}

fn main() {
    let a = Square {length: 5.2};
    println!("My square is {} long!", a.length);
}
```

Methods

```
impl Square {

    fn area(&self) -> f32 {
        self.length * self.length
    }


    fn grow(&mut self, factor: f32) {
        self.length *= factor;

    }
}
```

Methods

```rust
impl Square {
    fn new(l: i32) -> Self {
        Self {length: l}
    }
}

fn main() {
    let my_square = Square::new(3);
    println!("{}",my_square.length)
}
```

Vector

```rust
fn main() {
    let mut my_vec = Vec::new();
    my_vec.push(8);

    let mut my_other_vec = vec![1,2,3];

    for i in &mut my_other_vec {
        *i += 2;
    }

    let sum: i32 = my_other_vec.iter().sum();
    println!("{}", sum);
}
```

Slices

- Slices in Rust are similar to std::span and std::string_view in C++
- (possibly mutable) view to data owned somewhere else

https://gcc.godbolt.org/z/P7njMxfda

Traits

```rust
trait Shape {
    fn area(&self) -> f32;
}

impl Shape for Square {
    fn area(&self) -> f32 {
        self.length * self.length
    }
}

fn print_area(shape: &impl Shape) {
    println!("The area is {}", shape.area());
}
```

Generics and Trait Bounds

```
fn print_area<T: Shape>(shape: &T) {
    println!("The area is {}", shape.area());
}

fn print_area<T: Shape + Density>(shape: &T) {
}

fn some_function<T, U>(t: &T, u: &U) -> i32
    where T: Display + Clone,
          U: Clone + Debug
{ }
```

Derivable Traits

```rust
#[derive(Clone, Copy)]
struct Rectangle {
    width: u32,
    height: u32,
}

fn main() {
    let a = Rectangle {width: 5, height: 3};
    let b = a;
    println!("{}", a.width);
    println!("{}", b.width);
}
```

Trait Objects and Smart Pointers

- a trait object can represent any struct which implements the mentioned trait
- can be used to create vectors of different types which share a trait
- trait objects perform dynamic dispatch (similar to virtual function calls in C++)
- Box is smart pointer whose contents are stored on the heap

https://gcc.godbolt.org/z/EoT3ofzd3

Traits and Functions

https://gcc.godbolt.org/z/naPzb3j3T

Tuple-like Structs

```rust
struct Color(i32, i32, i32);
struct Point(i32, i32, i32);

fn main() {
    let black = Color(0, 0, 0);
    let origin = Point(0, 0, 0);
    let my_tuple = (1,2,3);
    let (x, _, _) = my_tuple;
    let Color (r,g,b) = black;
    println!("{} {} {}", r, g, b);
    println!("{} {}", origin.1, x);
}
```

Are there any questions?

Enums

```rust
enum Action {
    Stay,
    Move {x: i32, y: i32},
    Fight(i32),
    Say(String),
}

fn main() {
    let my_action = Action::Move {x: 12, y: 15};
}
```

Pattern Matching

```
fn main() {
    let my_action = Action::Move {x: 12, y: 15};
    let result = match my_action {
        Action::Stay => 5,
        Action::Move {x, y} => {println!("Moving");
                                x+y},
        _ => 20
    };
    println!("{}", result);
}
```

if let

```rust
fn main() {
    let my_action = Action::Move {x: 12, y: 15};
    let result = if let Action::Move {x,y} = my_action {  x+y }
    else {
        5
    };
    println!("{}", result);
}
```

Option

```
enum Option<T> {
    Some(T),
    None,
} //defined by standard lib

let some_number = Some(5);
let absent_number: Option<i32> = None;
```

Error Handling

```rust
use std::fs::File;

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

fn main() {
    let f = File::open("hello.txt");

    let f = match f {
        Ok(file) => file,
        Err(error) => panic!("Problem opening the file: {:?}", error),
    };
}
```

Error Handling

```
use std::fs::File;

fn main() {
    let f = File::open("hello.txt").unwrap();
    let g = File::open("world.txt").expect("Failed to open 
world.txt");
}
```

Error Handling: The ? operator

```
fn read_file() -> Result<File, io::Error> {
    let f = File::open("hello.txt");

    let f = match f {
        Ok(file) => file,
        Err(e) => return Err(e),
    };
    Ok(f)
}

fn main() {
    let my_file = read_file().unwrap();
}
```

Error Handling: The ? operator

```rust
use std::fs::File;
use std::io;

fn read_file() -> Result<File, io::Error> {
    let f = File::open("hello.txt")?;
    Ok(f)
}

fn main() {
    let my_file = read_file().unwrap();
}
```

Are there any questions?

Iterators

```rust
struct EvenNumbers {
    value: u32,
}

impl EvenNumbers {
    fn new() -> Self {
        Self { value: 2 }
    }
}

impl Iterator for EvenNumbers {
    type Item = u32;

    fn next(&mut self) -> Option<Self::Item> {
       let old_value = Some(self.value);
       self.value += 2;
       old_value
    }
}
```

Iterators

```rust
fn main() {
    let my_series = EvenNumbers::new();
    let result: u32 = my_series.skip(5).map(|x| x*x).take(10).sum();
    println!("{}", result);
}
```

Tooling: Cargo

https://github.com/hniemeyer/rust_tooling_demo

Are there any questions?

Interop with C++

- Rust ist cool but shall we rewrite our 1.5 million LOC C++ codebase in Rust?
- of course not
- Maybe new projects in Rust.
- what options do we have for interop are there?
- rust-bindgen (unsafe bindings, ffi)
- cxx crate (safe bindings, ffi)
- grpc (rpc) or Thrift (rpc)

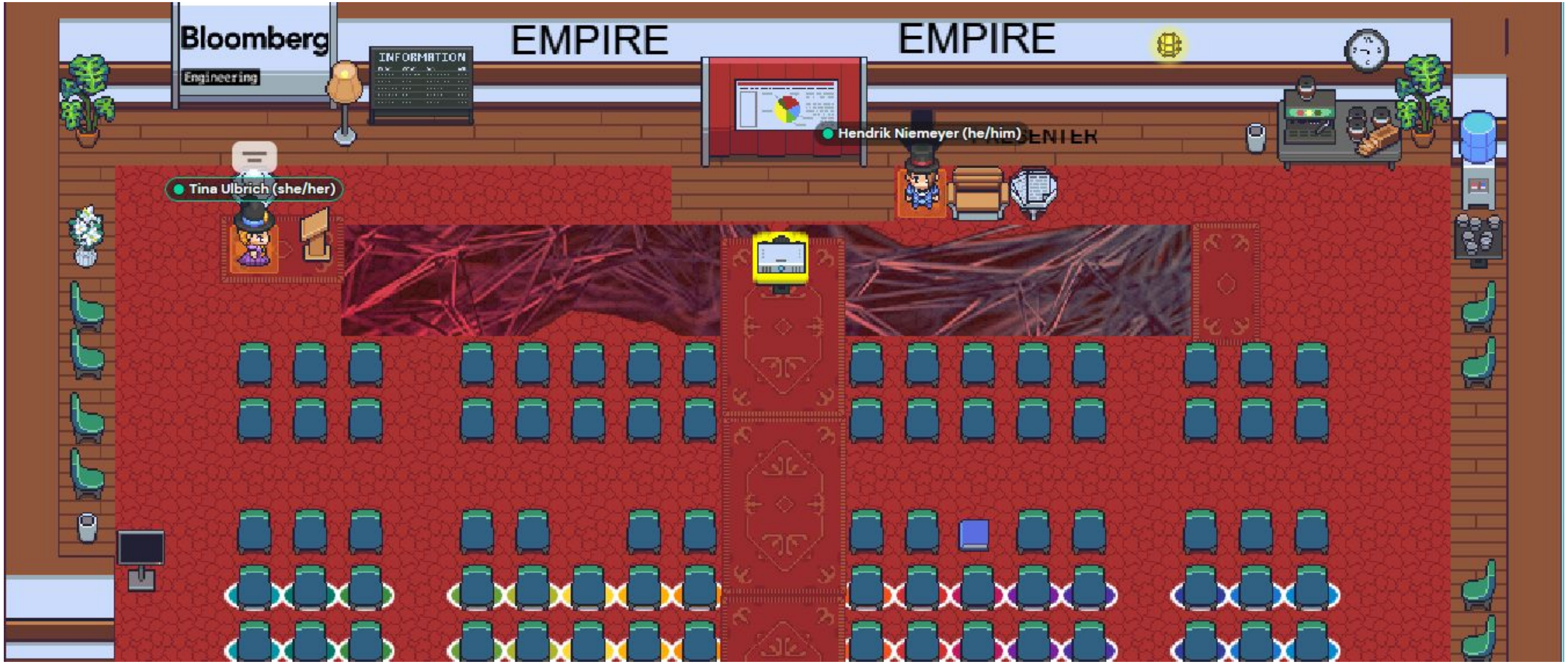
Interesting Topics for Further Exploration

- multithreading
- async
- WASM

Are there any questions?

My Other Talk

What Has C++20 Ever Done For Templates?: 11:00 - 12:30 Friday 8th April 2022 BST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INFORMATION
EMPIRE
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Tina Ulbrich (she/her)