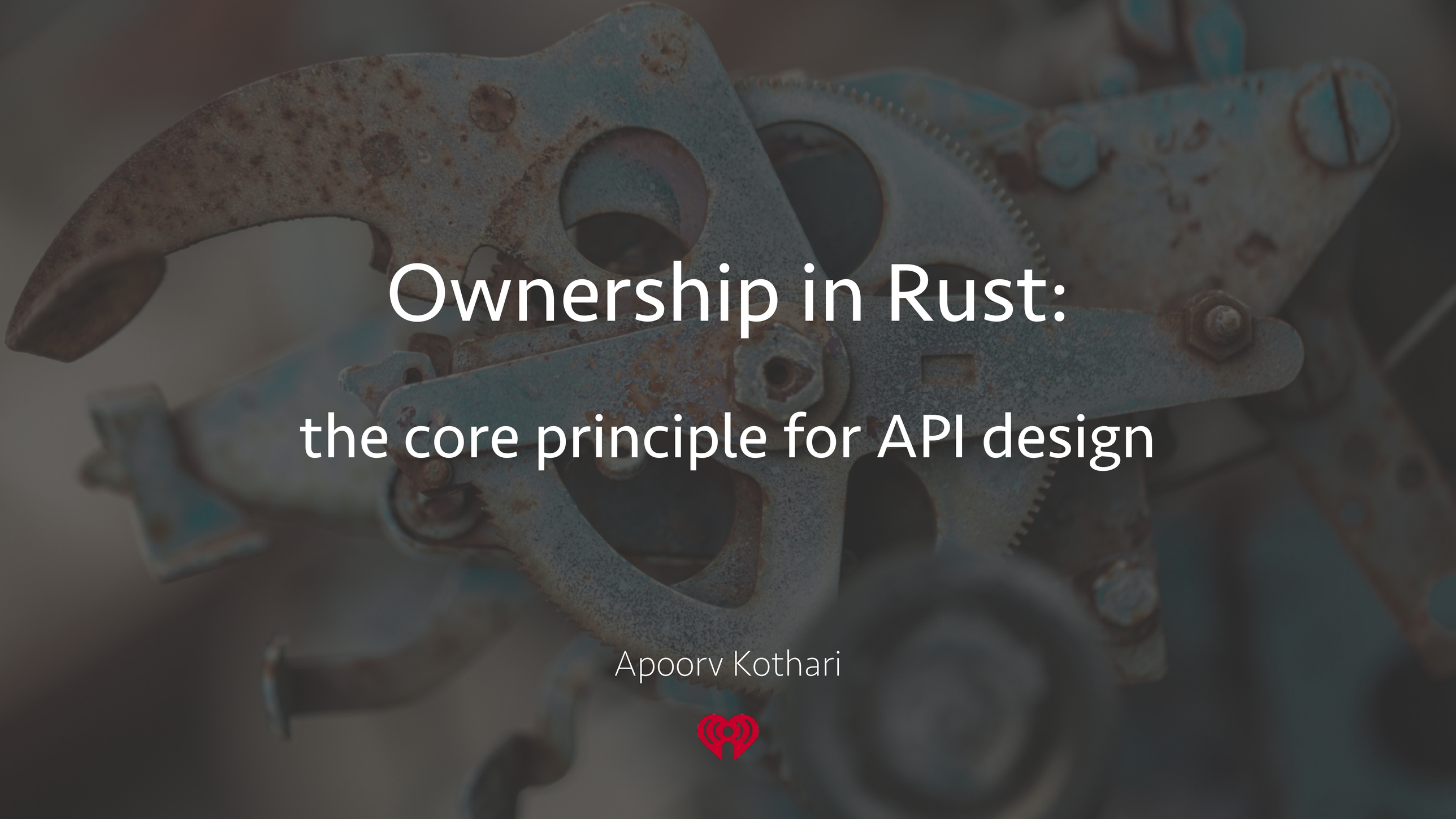

Ownership in Rust:

the core principle for API design

Apoorv Kothari

content

- what is ownership?
- motivation for ownership
- relevant ownership rules
- designing an API

what is ownership?

what is ownership?

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what is ownership?

```
let foo = 5;
```

- `value` is a property which says that **foo is equal to 5**
- `ownership` is a property which says **foo owns 5**
  - purely a compile-time property (no runtime cost)

what is ownership?

```
let foo = String::from("data");
```

what is ownership?

```
let foo = String::from("data");
let bar = foo;  // move ownership
```

what is ownership?

```
let foo = String::from("data");
let bar = foo;  // move ownership
println!(“{}”, foo);  // try to use moved value
```

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```
9  | let bar = foo;
   |     --- value moved here
10 | // invalid because foo no longer owns “data”
11 | println!("{}", foo);
   |                ^^^ value used here after move
```

what is ownership?

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let foo = String::from("data");
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what is ownership?

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   |                ^^^ value used here after move
```

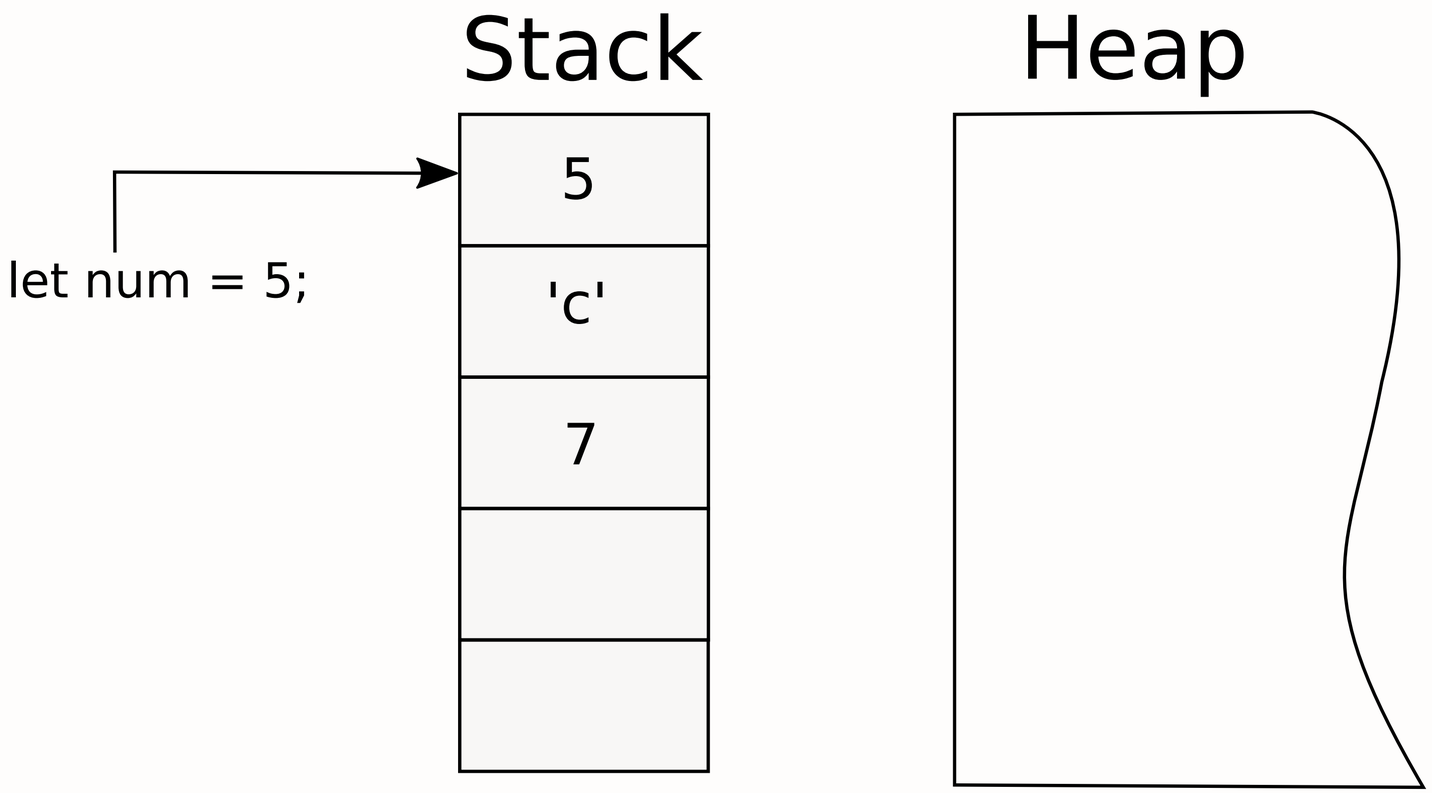
well actually... ownership/borrow/lifetimes

- these three make up the “ownership system” in Rust
- we will only cover **ownership** and **borrow**
- lifetimes:
  - is a concept used by the compiler
  - to measure when borrowed data goes of scope and
  - recover memory once data is finished being borrowed

motivation for ownership

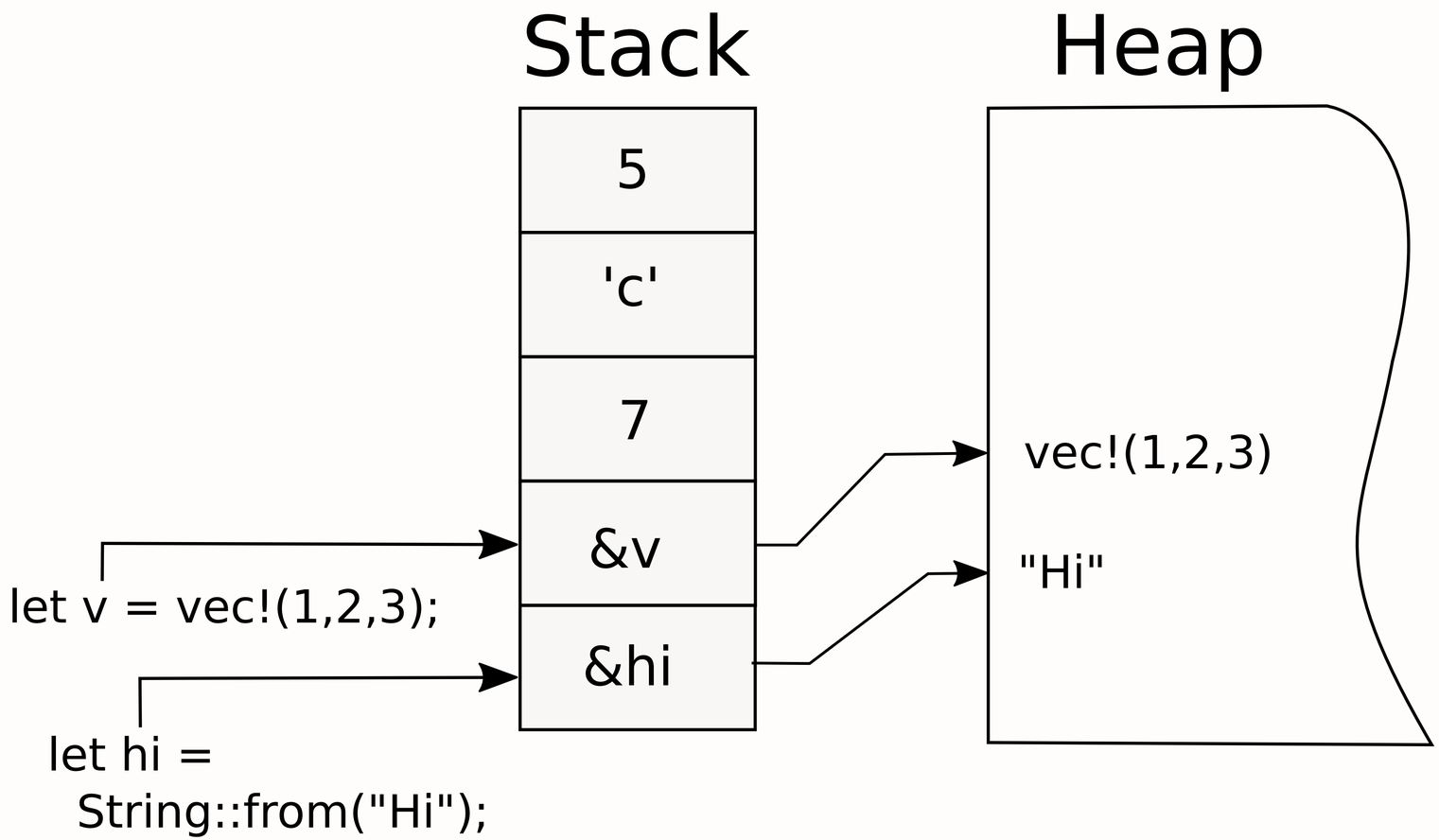
stack vs heap

- stack
  - u32, i32, bool, char, &, etc.
  - fast
  - limited space



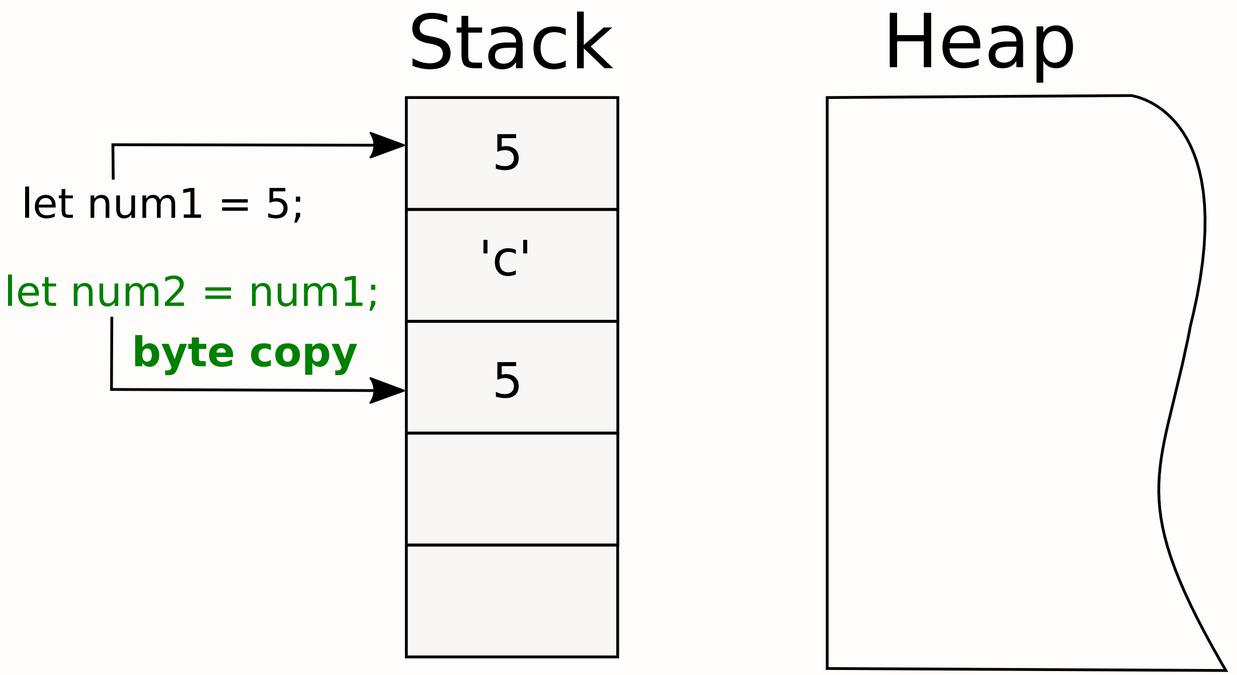
stack vs heap

- stack
  - u32, i32, bool, char, &, etc.
  - fast
  - limited space
- heap
  - String, Vector
  - slow
  - *unlimited size



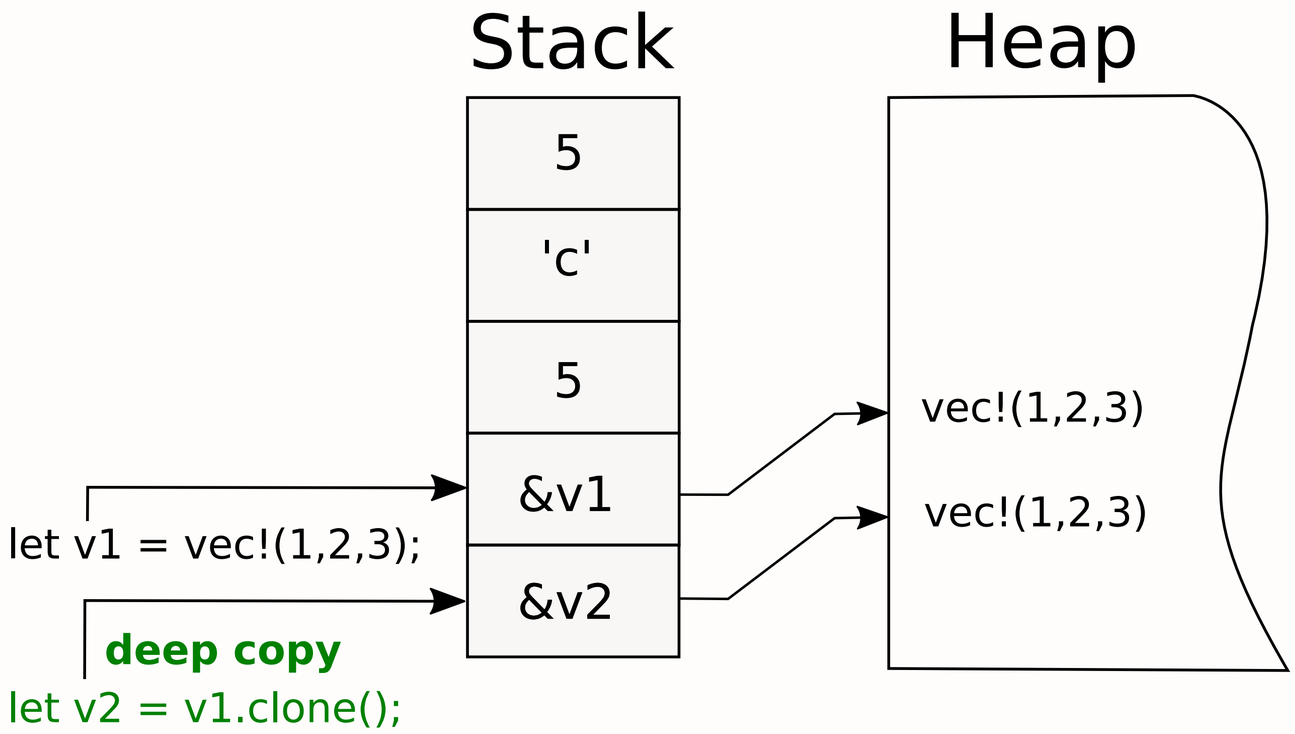
byte vs deep copy

- byte copy is the default behavior
  - copy the bytes representing 5

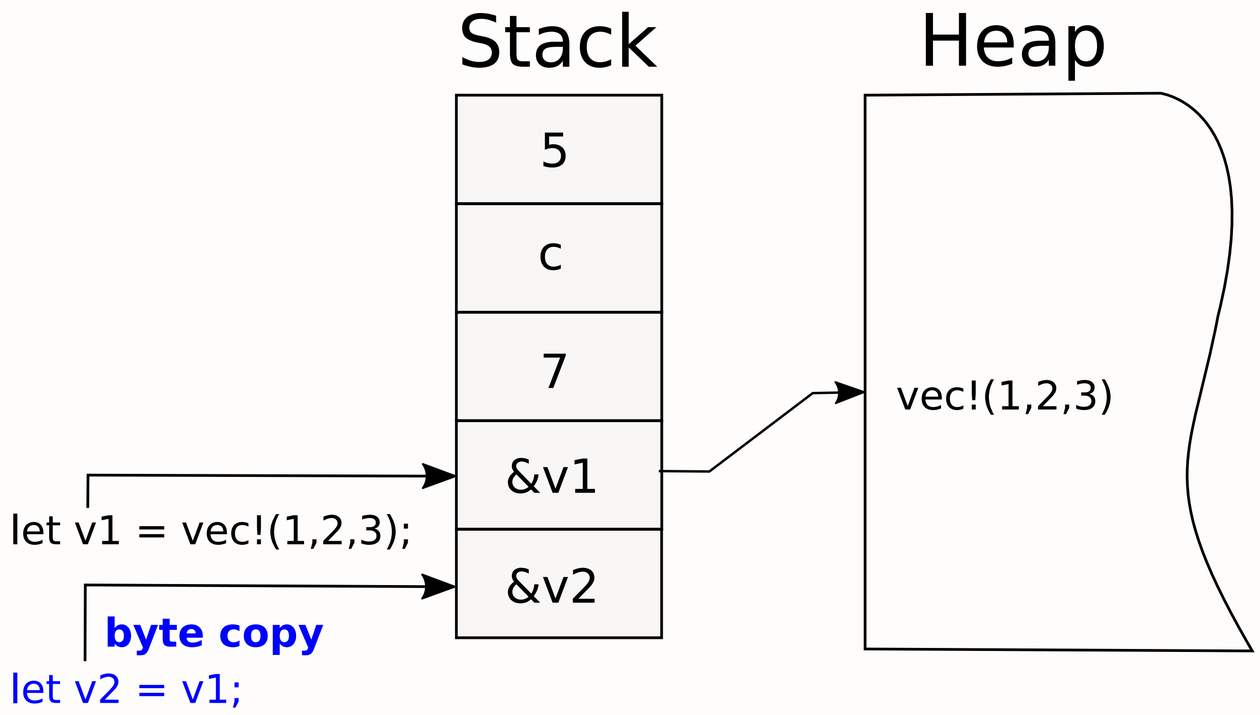


byte vs deep copy

- byte copy is the default behavior
  - copy the bytes representing 5
- deep copy is necessary for data living on the heap
  - follow all the pointers and copy data they point to

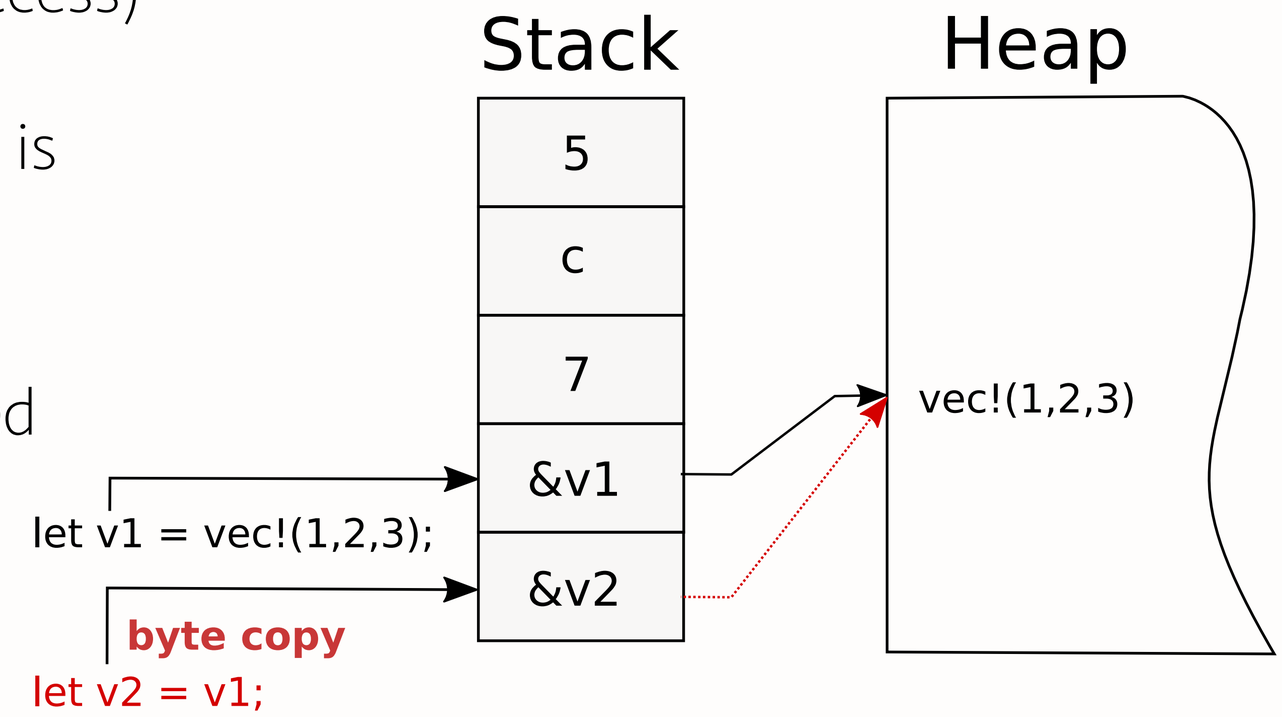


implication of byte copy



implication of byte copy

- overwriting data (multi-threaded access)
- undefined behavior (if vector length is changed)
- access neighbors data (compromised security)
- corrupting of data



solutions to the ‘copy’ problem

Copy Options	Speed	Safety
manage memory and use a GC process (Java)	no	yes
do a byte copy let the developer handle it (C)	yes	no
always do a deep copy	no	yes
invalidate previous variable by moving ownership (Rust)	yes	yes

relevant ownership rules

ways to share data in Rust

move
(ownership semantic)

```
let foo = String::from("data");
let bar = foo;
// foo is invalidated
```

ways to share data in Rust

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(ownership semantic)

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let foo = String::from("data");
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reference (&T)
(borrow semantic)

```
let foo = String::from("data");
let bar = &foo;
// foo is valid
```

ways to share data in Rust

move
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```
let foo = String::from("data");
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// foo is invalidated
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reference (&T)
(borrow semantic)

```
let foo = String::from("data");
let bar = &foo;
// foo is valid
```

mutable ref (&mut T)
(borrow semantic)

```
let mut foo = String::from("data");
let bar = &mut foo;
// foo is valid, but only 1 ref allowed
```

ways to share data in Rust

move (ownership)

```
let foo = String::from("data");
let bar = foo;
```

reference (&T) (borrow)

```
let foo = String::from("data");
let bar = &foo;
```

mutable ref (&mut T) (borrow)

```
let mut foo = String::from("data");
let bar = &mut foo;
```

NO RUNTIME COSTS

relevant ownership rules

- each value has a variable which is its owner /
  there can only be one owner at a time (ownership)
- you can have as many *&T* as you want (borrow)
- you can have only one *&mut T* in scope (borrow)

relevant ownership rules

each value has a variable which is its owner /
there can only be one owner at a time

```
let foo: String = String::from("data");
let bar: String = foo; //ownership moved
println!("{}", foo); //moved after use
```

```
9  | let bar = foo;
   |     --- value moved here
10 | // invalid because foo no longer owns “data”
11 | println!("{}", foo);
   |                ^^^ value used here after move
```

relevant ownership rules

you can have as many &T as you want

```
let foo = String::from("data");
let bar = &foo;  //create a reference
println!("{}", foo);  //foo still owns its data
println!("{}", foo);  //multiple reference allowed
```

you can have only one &mut T in scope

```
let mut foo = String::from("data");
let bar = &mut foo;  //create a mut reference
println!("{}", &foo);  //only 1 mut reference allowed
```

```
37 |          let bar = &mut foo;  //create a mut reference
   |                     --- mutable borrow occurs here
38 |          println!("{}", foo);  //only 1 mut reference allowed
   |                         ^^^ immutable borrow occurs here
40 |      }
   |      - mutable borrow ends here
```

designing an API

guarantees of the ownership system

- **move**: owner controls how long the data is *valid* for

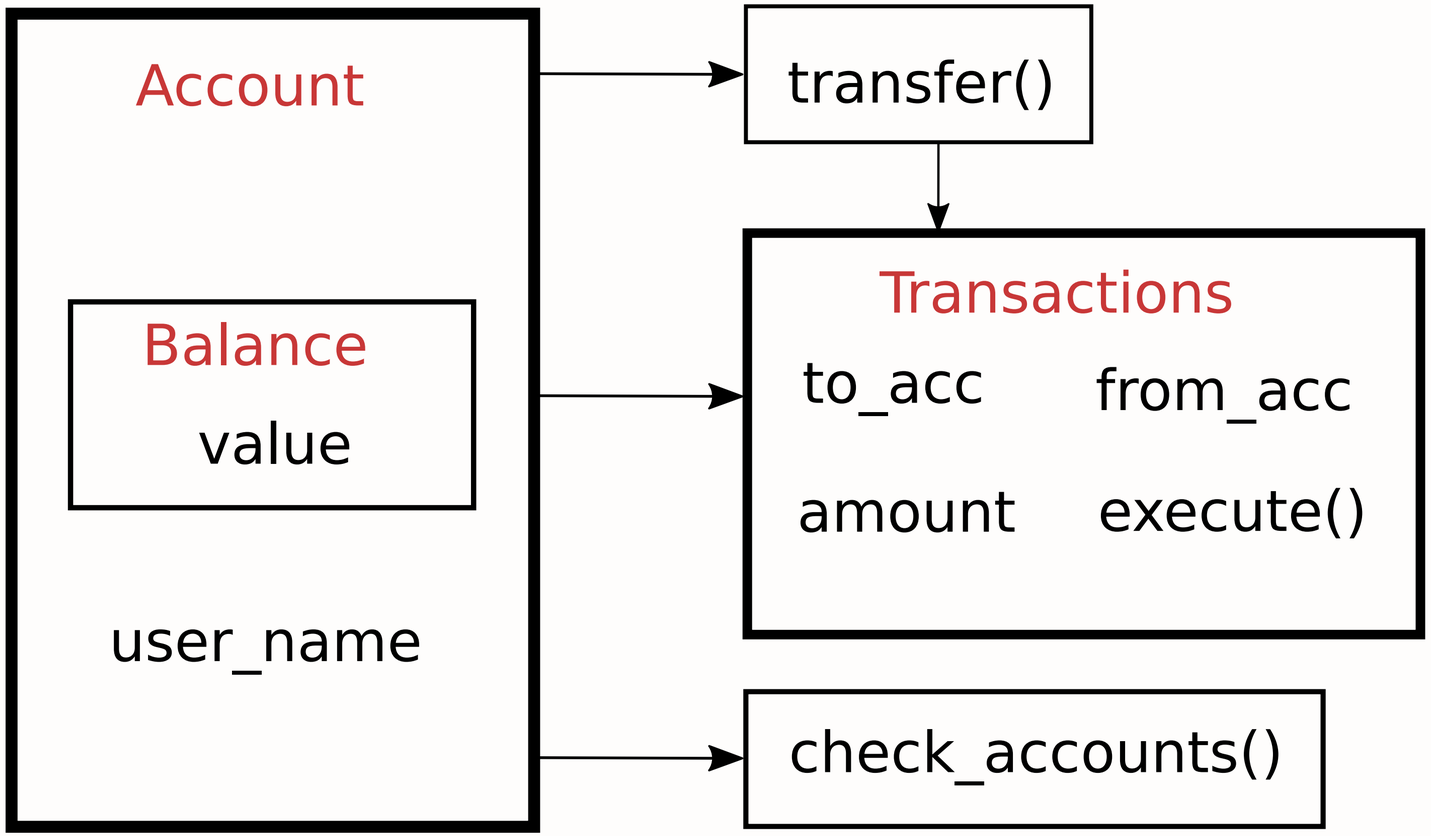
guarantees of the ownership system

- move: owner controls how long the data is valid for
- &T: *multiple immutable* reads are possible

guarantees of the ownership system

- move: owner controls how long the data is valid for
- &T: multiple immutable reads are possible
- &mut T: *mutation* is possible and there is only *one* &mut in scope!

bank API


Account
Balance
value
user_name
transfer()
Transactions
to_acc
from_acc
amount
execute()
check_accounts()

bank API

```
struct Account {
    user_name: String,
    balance: Balance,
}
```

```
struct Balance {
    value: u64,
}
```

bank API

```
struct Account {
    user_name: String,
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bank API

```
struct Account {
    user_name: String,
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}
```

```
struct Balance {
    value: u64,
}
```

bank API

```
struct Transaction<'a> {
    from: &'a mut Account,
    to: &'a mut Account,
    amount: u64,
}
```

```
impl<'a> Transaction<'a> {
    fn execute(&mut self) {
        self.from.balance.value -= self.amount;
        self.to.balance.value += self.amount;
    }
}
```

bank API

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struct Transaction<'a> {
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    to: &'a mut Account,
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struct Transaction<'a> {
    from: &'a mut Account,
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impl<'a> Transaction<'a> {
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        self.from.balance.value -= self.amount;
        self.to.balance.value += self.amount;
    }
}
```

bank API

```
fn check_accounts(acc: Vec<&Account>) {
    for i in acc {
        println!("{:?}", i);
    }
}
```

```
fn transfer(
    mut from: &mut Account,
    mut to: &mut Account,
    amount: u64) {
    Transaction { from, to, amount }.execute();
}
```

bank API

```
fn check_accounts(acc: Vec<&Account>) {
    for i in acc {
        println!("{:?}", i);
    }
}
```

```
fn transfer(
    mut from: &mut Account,
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    Transaction { from, to, amount }.execute();
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bank API

```
fn check_accounts(acc: Vec<&Account>) {
    for i in acc {
        println!("{:?}", i);
    }
}
```

```
fn transfer(
    mut from: &mut Account,
    mut to: &mut Account,
    amount: u64) {
    Transaction { from, to, amount }.execute();
}
```

bank API

```
fn main() {
    let alice_balance = Balance { value: 100 };
    let mut alice_acc = Account { user_name: String::from("alice"), balance: alice_balance };
    let bob_balance = Balance { value: 100 };
    let mut bob_acc = Account { user_name: String::from(“bob"), balance: bob_balance };
    check_accounts(vec![&alice_acc, &bob_acc]);

    { /* TRANSACTION 1: Restrict the scope to the block. */
        let mut transfer = Transaction { from: &mut alice_acc, to: &mut bob_acc, amount: 10 };
        transfer.execute();
    }
    check_accounts(vec![&alice_acc, &bob_acc]);

    /* TRANSACTION 2: Restricted scope because Transaction is not assigned. */
    transfer(&mut alice_acc, &mut bob_acc, 10);
    check_accounts(vec![&alice_acc, &bob_acc]);
}
```

bank API

```
fn main() {

    let alice_balance = Balance { value: 100 };
    let mut alice_acc = Account { user_name: String::from("alice"), balance: alice_balance };

    let bob_balance = Balance { value: 100 };
    let mut bob_acc = Account { user_name: String::from(“bob"), balance: bob_balance };

    check_accounts(vec![&alice_acc, &bob_acc]);

    ...
}
```

bank API

```
fn main() {

    let alice_balance = Balance { value: 100 };
    let mut alice_acc = Account { user_name: String::from("alice"), balance: alice_balance };

    let bob_balance = Balance { value: 100 };
    let mut bob_acc = Account { user_name: String::from(“bob"), balance: bob_balance };

    check_accounts(vec![&alice_acc, &bob_acc]);

    ...
}
```

bank API

```
fn main() {

    let alice_balance = Balance { value: 100 };
    let mut alice_acc = Account { user_name: String::from("alice"), balance: alice_balance };

    let bob_balance = Balance { value: 100 };
    let mut bob_acc = Account { user_name: String::from(“bob"), balance: bob_balance };

    check_accounts(vec![&alice_acc, &bob_acc]);

    ...
}
```

bank API

```
fn main() {

    let alice_balance = Balance { value: 100 };
    let mut alice_acc = Account { user_name: String::from("alice"), balance: alice_balance };

    println!("{:?}, alice_balance);

    let bob_balance = Balance { value: 100 };
    let mut bob_acc = Account { user_name: String::from(“bob"), balance: bob_balance };

    check_accounts(vec![&alice_acc, &bob_acc]);

    ...
}
```

bank API

```
fn main() {

    let alice_balance = Balance { value: 100 };
    let mut alice_acc = Account { user_name: String::from("alice"), balance: alice_balance };

    println!("{:?}, alice_balance);

    let bob_balance = Balance { value: 100 };
    let mut bob_acc = Account { user_name: String::from(“bob"), balance: bob_balance };

    check_accounts(vec![&alice_acc, &bob_acc]);

    ...
}
```

bank API

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fn main() {

    let alice_balance = Balance { value: 100 };
    let mut alice_acc = Account { user_name: String::from("alice"), balance: alice_balance };

    let bob_balance = Balance { value: 100 };
    let mut bob_acc = Account { user_name: String::from(“bob"), balance: bob_balance };

    check_accounts(vec![&alice_acc, &bob_acc]);

    ...
}
```

bank API

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    let bob_balance = Balance { value: 100 };
    let mut bob_acc = Account { user_name: String::from(“bob"), balance: bob_balance };

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    ...
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    { /* TRANSACTION 1: Restrict the scope to the block. */
        let mut transfer = Transaction { from: &mut alice_acc, to: &mut bob_acc, amount: 10 };
        transfer.execute();
    }
    check_accounts(vec![&alice_acc, &bob_acc]);

    /* TRANSACTION 2: Restricted scope because Transaction is not assigned. */
    transfer(&mut alice_acc, &mut bob_acc, 10);
    check_accounts(vec![&alice_acc, &bob_acc]);

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    }
    check_accounts(vec![&alice_acc, &bob_acc]);

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    ...

    { /* TRANSACTION 1: Restrict the scope to the block. */
        let mut transfer = Transaction { from: &mut alice_acc, to: &mut bob_acc, amount: 10 };
        transfer.execute();
    }  //`transfer` is dropped here
    check_accounts(vec![&alice_acc, &bob_acc]);

    /* TRANSACTION 2: Restricted scope because Transaction is not assigned. */
    transfer(&mut alice_acc, &mut bob_acc, 10);
    check_accounts(vec![&alice_acc, &bob_acc]);

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bank API

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    let mut alice_acc = Account { user_name: String::from("alice"), balance: alice_balance };
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    ...

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        transfer.execute();
    }
    check_accounts(vec![&alice_acc, &bob_acc]);

    /* TRANSACTION 2: Restricted scope because Transaction is not assigned. */
    transfer(&mut alice_acc, &mut bob_acc, 10);
    check_accounts(vec![&alice_acc, &bob_acc]);

}
```

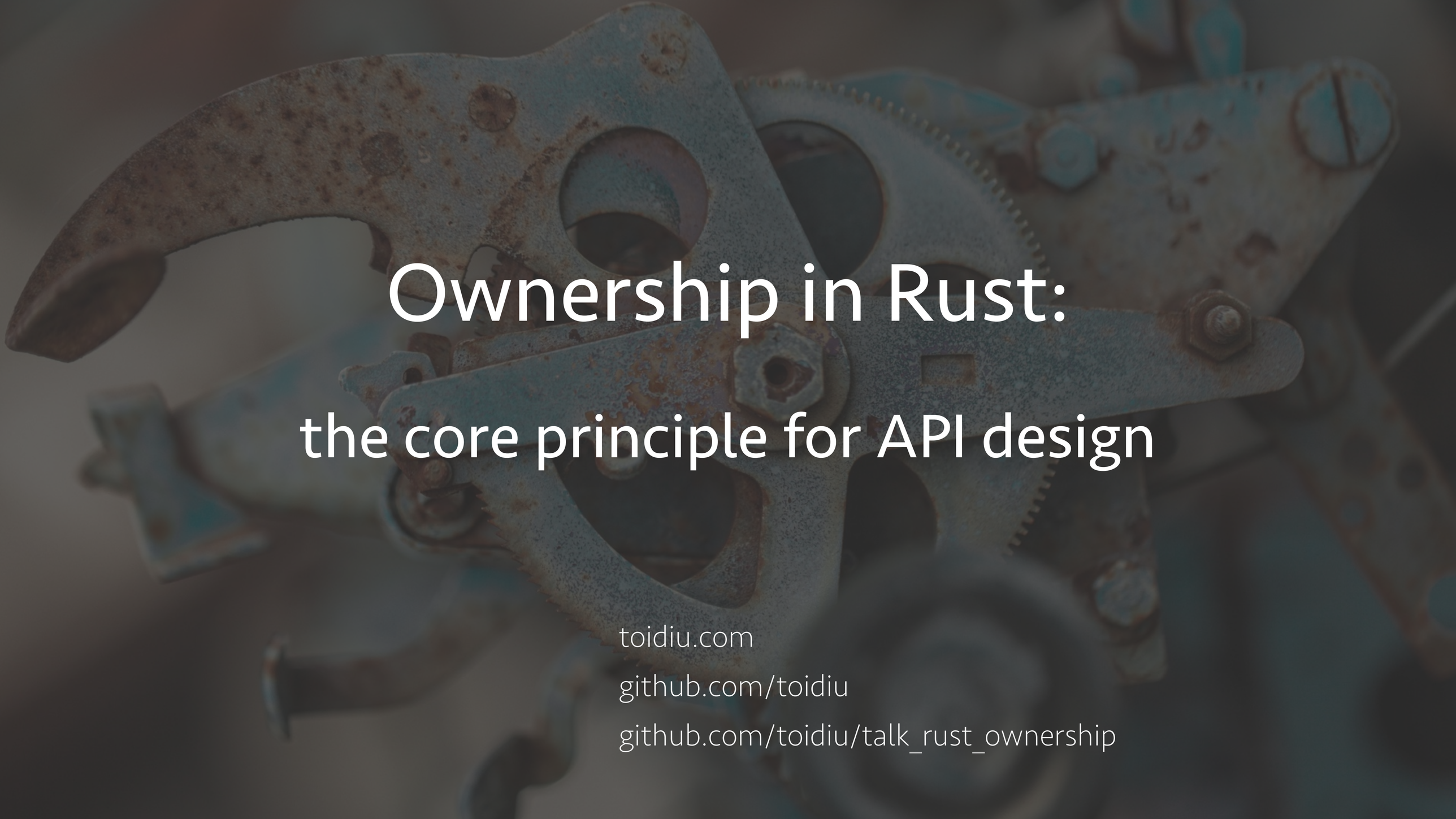
productivity tips (extra)

tools to becoming productive

- compiler driven development (CDD)
  - **cargo check** is faster than **cargo run**
  - **cargo-watch** (cargo check on file change)
- clippy (linter)
- cargo fmt (formatter)

references and thanks

- coworkers at iHeart Radio
- the Rust community
- Splash photo by Andrew Branch on Unsplash
- https://rustbyexample.com/
- https://doc.rust-lang.org/stable/book/first-edition/
- https://doc.rust-lang.org/stable/book/second-edition/
- https://stackoverflow.com/questions/79923/what-and-where-are-the-stack-and-heap
- https://stackoverflow.com/questions/373419/whats-the-difference-between-passing-by-reference-vs-passing-by-value
- https://stackoverflow.com/questions/24253344/move-vs-copy-in-rust?answertab=active#tab-top
- https://blog.rust-lang.org/2017/03/16/Rust-1.16.html



Ownership in Rust:

the core principle for API design

toidiu.com

github.com/toidiu

github.com/toidiu/talk_rust_ownership