

# Typeclasses

## Ownership and Borrowing in Rust

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### Why Learn another language?

- Not all languages stay popular forever
  - There may be interesting work in other languages
  - You can apply the patterns of another language to your current language
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### Why Rust?

- Memory safe
  - Fast
  - Correctness as a feature
  - Statically Linked Binaries
  - Strong type system
  - Functional programming
  - Fearless Concurrency
  - **Unique ownership system**
- 

### Memory Safety

- Does this compile?
- what does it print?

```
#include <bits/stdc++.h>
using namespace std;

int main() {
    vector<tuple<int, int>> vec = {{5, 10}};
```

```
const auto &first_elem = vec.front();  
for (int i = 0; i < 10; ++i) vec.push_back(first_elem);  
for (const auto [x, y]: vec) cout << x << ' ' << y << '\n';  
}
```

---

### Memory Safety Cont.

It does, rather confusingly:

```
5 10  
5 10  
0 0  
0 0  
0 0  
0 0  
0 0  
0 0  
0 0  
0 0  
0 0  
0 0
```

---



## Iterator Invalidation

- Does this compile?
- what does it print?

```
#include <bits/stdc++.h>
using namespace std;

int main() {
    vector<string> strings = {"Hi"};
    const auto& elem = strings[0];
    strings.push_back("World");
    cout << elem << '\n';
}
```

---

## Iterator Invalidation Cont.

- This is undefined behavior. It could print nothing or segfault or uninitialized memory.



Let's try this in rust.

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## Rust Memory Safety

- Does this compile?
- If so, what does it print?

```
fn main() {  
    let mut vec = vec![(5, 10)];  
    let first_elem = &vec[0];  
    for _ in 1..10 { vec.push(*first_elem); }  
    for p in vec { println!("{}", p.0, p.1); }  
}
```

---

```
error[E0502]: cannot borrow `vec` as mutable because  
it is also borrowed as immutable
```

```
--> src/main.rs:4:22  
|  
3 |     let first_elem = &vec[0];  
|                       --- immutable borrow occurs here  
4 |     for _ in 1..10 { vec.push(*first_elem); }  
|                       ~~~~~^  
|                       |           |  
|                       |           immutable borrow  
|                       |           later used here  
|                       mutable borrow occurs here
```

```
error: aborting due to previous error
```

---



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## Strings

- Does this compile?
- If so, what does it print?

```
fn main() {  
    let mut vec = vec![String::from("Hi")];  
    let first_elem = &vec[0];  
    vec.push(first_elem.to_string());  
    println!("{}", first_elem);  
}
```

---

error[E0502]: cannot borrow `vec` as mutable because  
it is also borrowed as immutable

```
--> src/main.rs:4:5  
  |  
3 |     let first_elem = &vec[0];  
  |                       --- immutable borrow occurs here  
4 |     vec.push(first_elem.to_string());  
  |     ~~~~~ mutable borrow occurs here
```

```
5 | println!("{}", first_elem);  
  | ----- immutable borrow later used here
```

---



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### Ownership Rules

- You can give away as many copies as you want to.
  - You are allowed to have as many immutable references as you want **or**
  - You can loan out one mutable reference.
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### Define Ownership

- A copy gives ownership of a copy to someone.
    - I give you a copy of my book
  - A move gives ownership to someone.
    - I give you my book
  - A reference shares ownership of code with someone.
    - We share the book
-

Is this program ok?

```
#include <bits/stdc++.h>
using namespace std;

void print_arr(const vector<int> &vec);

int main() {
    print_arr({1,2,3,4});
}
```

---

Does it look fine now?

```
#include <bits/stdc++.h>
using namespace std;

void print_arr(const vector<int> &vec) {
    for (const auto elem: vec) cout << elem << '\n';
    delete &vec;
}

int main() {
    print_arr({1,2,3,4});
}
```

---

Types can't save us

- We have a problem where we try to delete a vector through a reference. This compiles.
  - Our program crashes immediately.
- 

In Rust

```
fn print_vec(vec: &Vec<i32>) {
    for item in vec {
        println!("{}", item);
    }
    drop(*vec);
}

fn main() {
    print_vec(&vec![1,2,3,4]);
}
```

---

```

error[E0507]: cannot move out of `*vec` which is behind
a shared reference
--> src/main.rs:5:10
5 |     drop(*vec);
  |           ^^^^^ move occurs because `*vec` has type
  |                 `std::vec::Vec<i32>`,
  |                 which does not implement the `Copy` trait

```

---

## Fearless Concurrency

```

#include <bits/stdc++.h>
using namespace std;

vector<int> nums;
void writeToNums() {
    for (int i = 0; i < 3; i++)
        nums.push_back(i);
}

int main() {
    vector<thread> threads;
    for (int i = 0; i < 20; i++) threads.emplace_back(writeToNums);
    for (auto& th: threads) th.join();
    for (auto item: nums) cout << item << ' ';
}

```

---

Undefined behavior again.

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## In Rust

```

use std::thread;
fn write_to_nums(nums: &mut Vec<i32>) {
    for i in 0..3 {
        nums.push(i);
    }
}

fn main() {
    let mut nums = vec![];
    let mut threads = vec![];
}

```



```

for _ in 0..20 {
    threads.push(thread::spawn(move || {
        write_to_nums(&mut nums);
    }));
}
for thread in threads {
    let _ = thread.join();
}
for num in nums {
    println!("{}", num);
}
}

```

---

```

error[E0382]: use of moved value: `nums`
--> src/main.rs:13:32

```

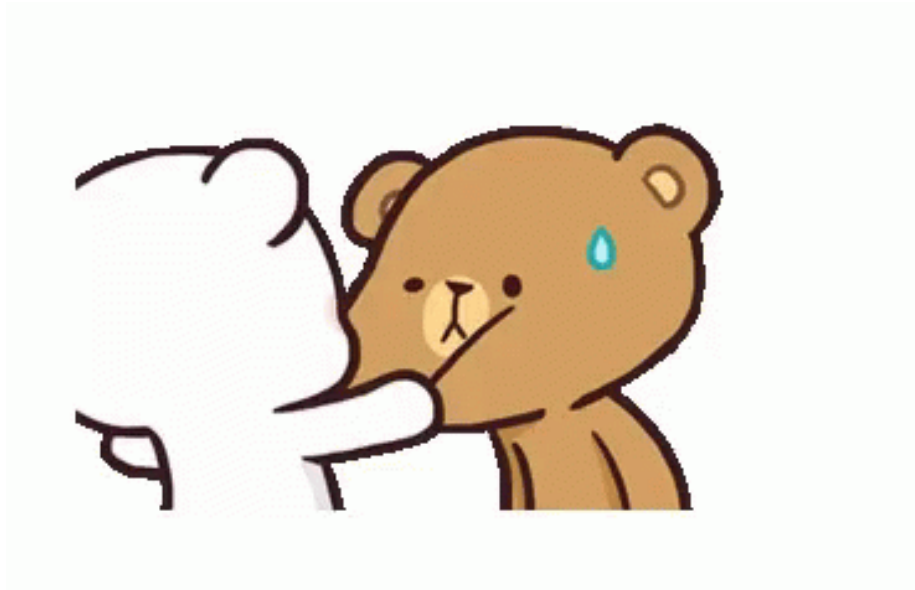
```

9 |   let mut nums = vec![];
  |   ----- move occurs because `nums` has type
  |   ----- `std::vec::Vec<i32>`, which does
  |   ----- not implement the `Copy` trait
...
13 |   threads.push(thread::spawn(move || {
  |                               ^^^^^^^ value moved into
  |                               closure here, in previous iteration of loop
14 |   write_to_nums(&mut nums);
  |               ^^ use occurs due to use in closure

```

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The Borrow Checker at first



The Borrow Checker by the end

