Ownership in Rust

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
```

Iterator Invalidation

- Does this compile?
- what does it print?

```cpp
#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.

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
```

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
```

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.

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

```cpp
#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.

In Rust

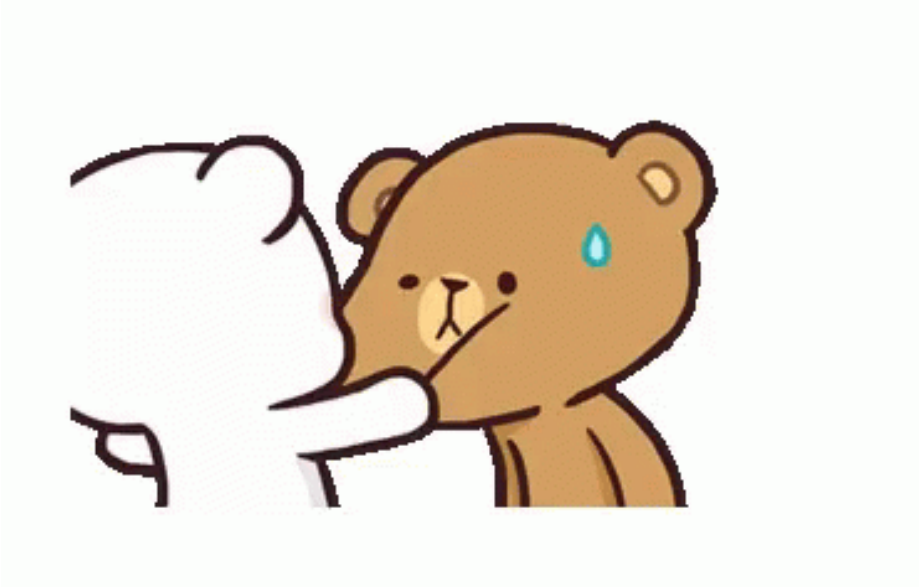
```rust
use std::thread;
fn write_to_nums(nums: &mut Vec<i32>) {
  for i in 0..3 {
    nums.push(i);
  }
}

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
```

The Borrow Checker at first



The Borrow Checker by the end