Ownership and Borrowing and Lifetimes (Oh My!)

EECS 395 “Rust”

Jan. 26, 2016
Definitions

An *object* is a chunk of memory with a type

Examples:

- The number 4 is a *value*, not an object.
- A word of memory containing the number 4 is an object.

*A variable* is the name of an object
Ownership

Every object in Rust has an owner. Either:

- a variable, or
- some other object
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- some other object

Ownership comes with rights and responsibilities:

- The owner is allowed to modify the object
- The owner is responsible for freeing the object
Transferring ownership

Ownership can be transferred:

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pub fn inc_vec(mut v: Vec<usize>, ix: usize) {
    v[ix] += 1;
}
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#[test]
fn test_inc_vec() {
    let expected = vec![3, 4, 6];
    let actual = vec![3, 4, 5];

    inc_vec(actual, 2);

    assert_eq!(expected, actual);
}
```
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pub fn inc_vec(mut v: Vec<usize>, ix: usize) {
    v[ix] += 1;
}

#[test]
fn test_inc_vec() {
    let expected = vec![3, 4, 6];
    let actual = vec![3, 4, 5];

    inc_vec(actual, 2);
    assert_eq!(expected, actual); // Error! actual has been moved
}
```
One solution: FP style

```rust
pub fn inc_vec(mut v: Vec<usize>, ix: usize) -> Vec<usize> {
    v[ix] += 1;
    v
}

#[test]
fn test_inc_vec() {
    let expected = vec![3, 4, 6];
    let mut actual = vec![3, 4, 5];
    actual = inc_vec(actual, 2);
    assert_eq!(expected, actual);
}
```
The Rust solution: borrowing

```rust
pub fn inc_vec(v: &mut Vec<usize>, ix: usize) {
    v[ix] += 1
}

#[test]
fn test_inc_vec() {
    let expected = vec![3, 4, 6];
    let mut actual = vec![3, 4, 5];

    inc_vec(&mut actual, 2);
    assert_eq!(expected, actual);
}
```
More idiomatic: take a slice

```rust
pub fn inc_vec(v: &mut [usize], ix: usize) {
    v[ix] += 1
}

#[test]
fn test_inc_vec() {
    let expected = vec![3, 4, 6];
    let mut actual = vec![3, 4, 5];

    inc_vec(&mut actual, 2);
    assert_eq!(expected, actual);
}
```
Borrowing implements reader/writer semantics

You can borrow

- as many immutable references as you like, or
- one mutable reference.

```rust
let mut x = SomeObject::new();
{
    let r1 = &x;
    let r2 = &x;
    let r3 = r1;
    let r4 = &mut x; // error!
}
{
    let r5 = &mut x; // ok
    let r6 = &x; // error!
}
```
Hidden borrows

Method calls may (mutably) borrow self
When borrowing won’t do

- The **Copy** trait for cheap copies
- The **Clone** trait for expensive copies
The Copy trait

Types implementing the Copy trait are copied implicitly rather than moved:

- usize and other numeric types
- &str and other borrowed reference types
- In general, types that
  - are cheap to copy (small), and
  - don’t involve a resource

```rust
let a = 5;
let b = a;
f(a);
let c = a + b;
```
The Clone trait supports explicit copying:

- **String, Vec, HashMap, etc.**
- In general, types that
  - may be expensive to copy, and
  - don’t involve a *unique resource* (e.g., a file handle)

```rust
let v = vec![3, 4, 5];
let u = v.clone();
f(v);
g(u);
```
Lifetimes

Objects have lifetimes (or more precisely, death times)

```rust
{
    let mut r: &str;

    {
        let s = String::new()
        r = &s; // error because r outlives s
    } // s dies here

    // r dies here
}
```
Lifetimes

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```rust
let mut r: &str;

{
    let s = String::new();
    r = &s;   // error because r outlives s
}

// s dies here
// r dies here
```

A reference must die before its referent!
The static lifetime

The only named lifetime is 'static—the lifetime of the whole program

String slice literals have the static lifetime. That is,

```rust
let s: &str = "hello";
```

means

```rust
let s: &'static str = "hello";
```
Lifetime variables

Other lifetimes are relative:

```rust
fn choose<'a, T>(x: &'a T, y: &'a T) -> &'a T
```