ECE326

PROGRAMMING LANGUAGES

Lecture 28 : Introduction to Rust

Kuei (Jack) Sun

ECE

University of Toronto

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Introduction

- Designed and developed at Mozilla Research
- First released in Summer 2010
  - Stable since Spring 2015
- Systems language focused on *safety*
  - Type safety, memory safety, safe concurrency
- Performance comparable to C/C++
- Compiler performs extensive safety checks
  - Compile time an be much slower than C/C++ compilers
- Syntactically similar to C/C++ and Haskell

Installation

- Custom installed on UG machines
- Add RUSTUP_HOME to environment variable
  - `setenv RUSTUP_HOME /cad2/ece326f/rust   # add to ~/.cshrc`
  - `export RUSTUP_HOME=/cad2/ece326f/rust   # add to ~/.bashrc`
- Run `rustc --version`
  - Make sure you get this output:
    - `rustc 1.38.0 (625451e37 2019-09-23)`
- https://rustup.rs/
  - Installs latest version of Rust
    - Follow its instruction to install for your home machine

Alias in Rust

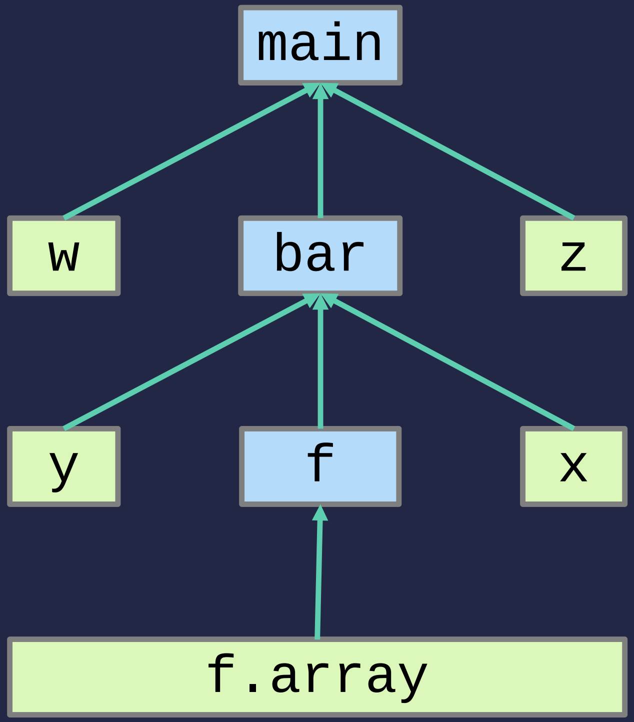
- No aliases
  - Cannot have two pointers pointing to same memory address
  - Guarantees memory safety without garbage collection
  - Compiler can deduce when to free memory
- Ownership
  - All lvalues have unique owners
    - E.g. the owner of local variables is their function
  - When the owner goes out of scope, it frees what it owns
  - Without alias, no cycles can be formed
    - Memory ownership will take the shape of a tree

Ownership

```
struct Foo {
	int * array;
	Foo() : array(new int[5]) {}
};

int bar(int y) {
	Foo f;
	int x = y + 3;
	return x + f.array[0];
}

int main() {
	int * w = new int(5);
	int z = bar(*w);
	return z;
}
```



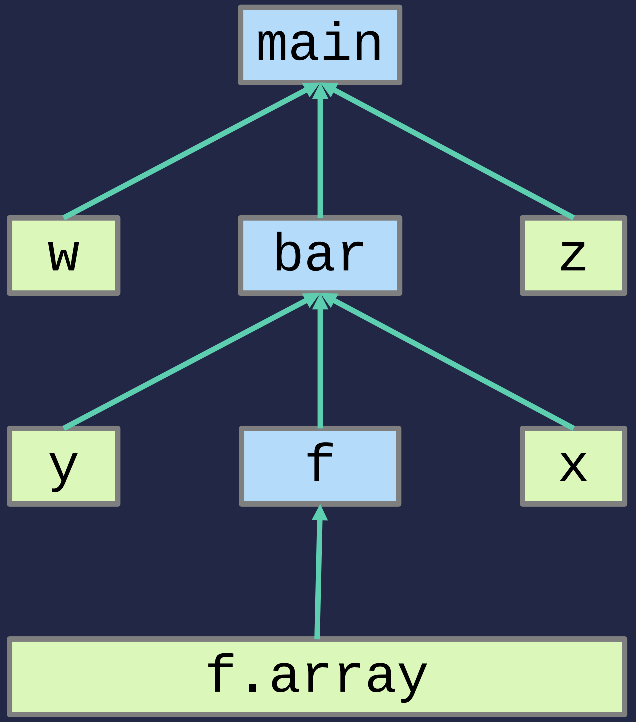
Ownership

```
struct Foo {
    int * array;
    Foo() : array (new int[5]) {}
    ~Foo() { delete array; }
};

int bar(int y) {
    Foo f;
    int x = y + 3;
    return x + f.array[0];
}

int main() {
    int * w = new int(4);
    int z = bar(*w);
    delete w;
    return z;
}
```

delete statements automatically inserted by compiler after static analysis of ownership

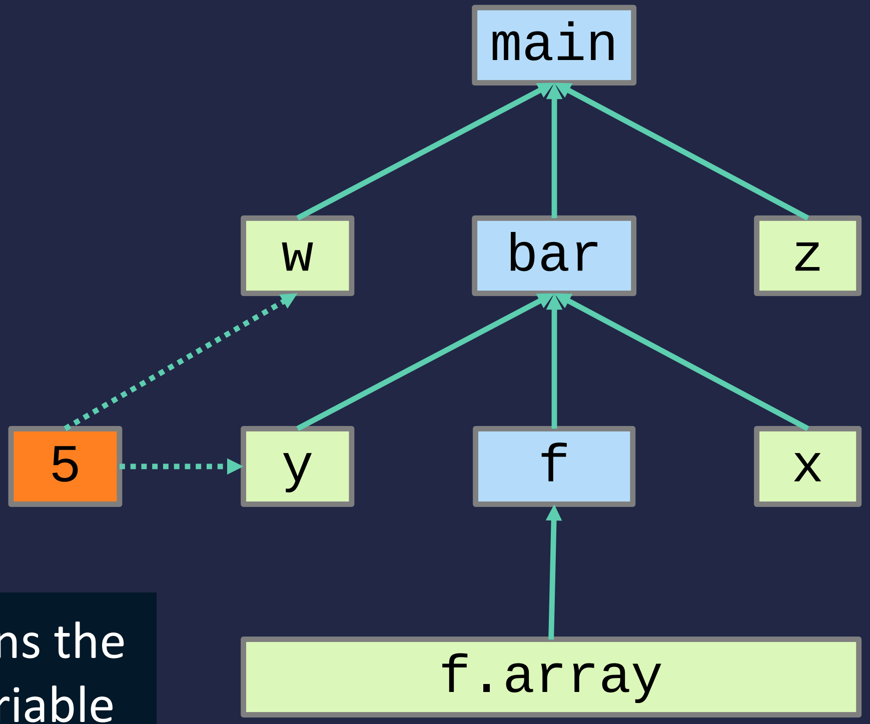


Passing Variable

```
struct Foo {
        int * array;
        Foo() : array(new int[5]) {}
};

int bar(int * y) {
        Foo f;
        int x = *y + 3;
        return x + f.array[0];
}

int main() {
        int * w = new int(5);
        int z = bar(w);
        return z;
}
```



Who owns the heap variable “5” now?

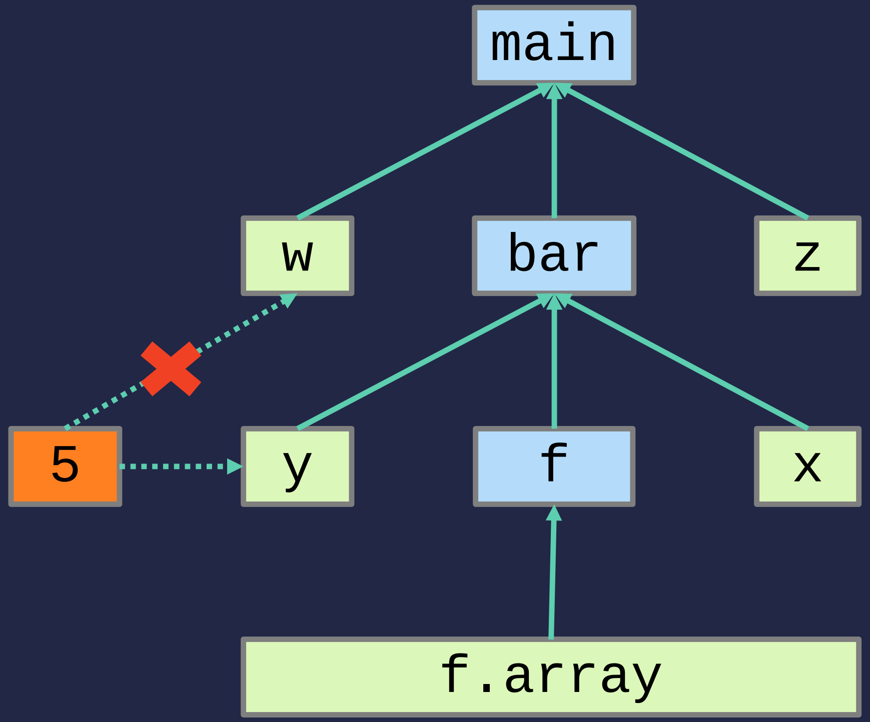
1. Takeover (Move)

```
struct Foo {
        int * array;
        Foo() : array(new int[5]) {}
};

int bar(int * y) {
        Foo f;
        int x = *y + 3;
        delete y;
        return x + f.array[0];
}

int main() {
        int * w = new int(5);
        int z = bar(w);
        /* cannot use w anymore */
        return z;
}
```

By default, bar takes over ownership.



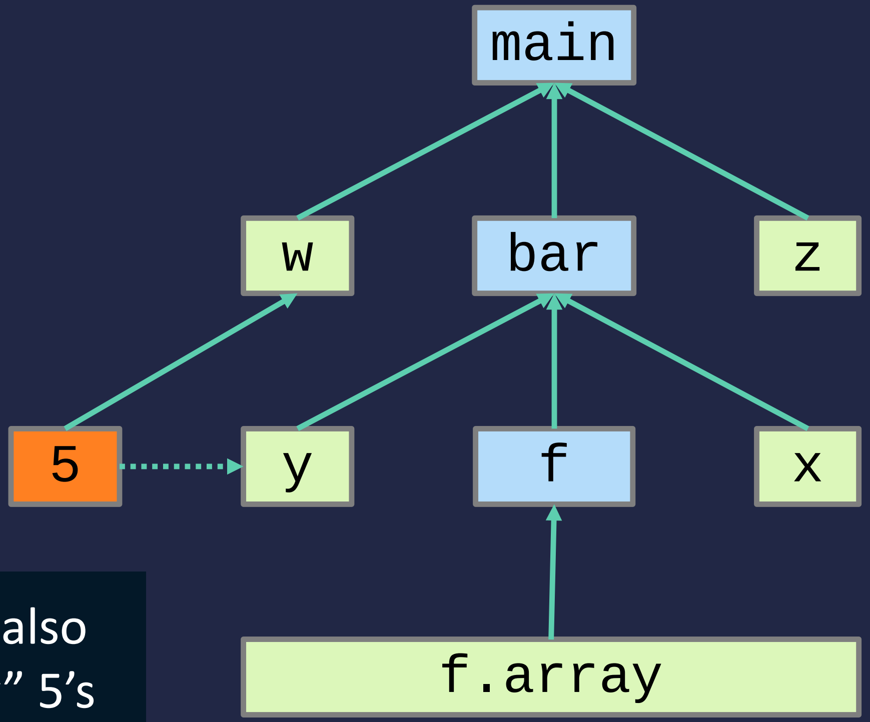
2. Borrow

```
struct Foo {
        int * array;
        Foo() : array(new int[5]) {}
};

int bar(borrowed int * y) {
        Foo f;
        int x = *y + 3;
        return x + f.array[0];
}

int main() {
        int * w = new int(5);
        int z = bar(w);
        delete w;
        return z;
}
```

bar can also "borrow" 5's ownership from main



Ownership

- Borrow
  - Lender must *outlive* borrower
- Lifetime
  - Interval in which an entity is valid
  - Begins when a variable is created, ends when it’s destroyed
- Passing variable
  - If variable can be copied (e.g. primitive types), pass by value
  - If parameter declared as borrow, lend variable *if possible*
  - Otherwise, performs a move (give up ownership)

Hello World

- Like in C/C++, requires a main function
- Function declared using **fn** keyword
- println! is a *macro* function (denoted by ! symbol)
- To compile, call `rustc -o hello main.rs`
  - hello is the name of executable

```
/* main.rs */
// Rust uses same as C/C++ comments
fn main() {
	println!(“hello world”);
}
```

Function

- General syntax

```
fn funcname(argname: argtype…) -> returntype {
      … statements …
      returnvalue
}
```

- In Rust, the last expression (no semicolon) is returned

```
fn foo(a: f64, b: f64) -> f64 {
      a * b               // return value
}

fn baz(a: f64, b: f64) -> f64 {
      return a * b;       // same as above
}
```

Variable

- Variable declaration in Rust is a *statement*
- Type can usually be automatically deduced
  - If assigned a literal, it has the type of the literal
  - If assigned a return value from a function, the return type

```
fn baz(a: f64, b: f64) -> f64 {
      return a * b;     // same as above
}

let a = 20;             // an integer type (e.g. i32 or i64)
let b: i64 = 30;        // explicitly specified as i64
let c = baz(2.0, 3.0);  // f64 by type inference
```

Strongly Typed

- Does not allow implicit conversion, even if its widening
- Use `as` operator to cast between types

```
let a: i32 = 1;
let b: i64 = 2;
let c = a * b;    // FAIL – does not allow implicit conversion

error: cannot multiply `i64` to `i32`

let c = a as i64 * b;
let x = [1, 2, 3];
println!("{}", x[a]);

error: cannot be indexed by `i32`
```

Println Format

- Similar to Python's string.format()
- Each set of curly braces is an argument
- Type conversion automatically done (coerce to string)
  - Argument needs to implement Display or Debug trait
    - For now, it is similar to overriding a virtual function in base class

```
let s = "hello world";
let a = 5;

println!("{}, {}", s, a);

hello world, 5
```

Immutability

- By default, variables in Rust are *constant* (immutable)
- If you want to change it, use **mut** keyword

```
let x = 5;
println!("The value of x is: {}", x);
x = 6;              // BAD!

error: cannot assign twice to immutable variable

let mut x = 5;
x = 6;              // OK
```

Constant

- Constant in Rust behaves like constexpr in C++
- It is a compile-time expression
- Can be declared in global scope (unlike **let**)
- Type must be specified

```
const MAX_POINTS: u32 = 100_000;
```

- underscore in literal has no semantic meaning
  - It helps programmer to more easily read bigger numbers

Shadowing

- Rust allows same name to be used multiple times
- Previous bindings are “shadowed”, cannot be accessed
- Useful once code becomes more complex

```
let x = 5;
let x = x + 1;
let x = x * 2;
println!("The value of x is: {}", x);

The value of x is: 12

let spaces = "   ";
let spaces = spaces.len();    // OK to change type as well
```

Primitive Types

- Boolean
  - true or false
- Floating Point
  - f32 or f64
- Integer
  - signed: i8, i16, i32, i64, isize
  - unsigned: u8, u16, u32, u64, usize
  - usize and isize depends on architecture (either 32 or 64 bits)
- Character
  - char
  - Can be unicode characters as well. Not just ASCII.
    - i.e. Unlike char in C, not guaranteed to be 1 byte

String

- utf-8 encoded (thus supports unicode characters)
- String literal
  - The type is &str (reference to a string slice)

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

- String slice
  - Reference to immutable string data somewhere
    - String literals are stored in program binary
  - Similar to `const char *` in C++

String

- String type
  - mutable string, content can be updated

```
let mut s1 = String::from("foo"); // convert to mutable
s.push_str("bar");                // append “bar” to s

let mut s2 = "lo".to_string(); // another way to convert
s.push('l');                    // push a single character

let mut s3 = String::new();     // creates an empty string

// formatted string (created from a macro function)
let s = format!("{}-{}-{}", s1, s2, s3);
```

Tuple

- Rust has built-in tuple type, similar to Python

```
let tup: (i32, f64, u8) = (500, 6.4, 1);
```

- Allows for unpacking

```
let tup = (500, 6.4, 1);
let (x, y, z) = tup;
```

- Also allows access to each element

```
let a = tup.0;
let b = tup.1;
let c = tup.2;
```

Array

- Similar in syntax to C array
- Performs compile time bound checking
- Tracks its own length, similar to Java array

```
let a = [1, 2, 3, 4, 5];
let months = ["January", "February", "March", "April", …];
let first = a[0];
let second = a[1];

// array does not support Display trait, must use {:?}
println!("{:?}: {}", a, a.len());

[1, 2, 3, 4, 5]: 5
```

Function

- Does not support function overloading
- Does not support default parameters
- Like in C, uses block scoping
- Blocks are expressions in Rust!

```
let y = {
    let x = 3;
    x + 1
};

println!("The value of y is: {}", y);     // 4
```

Unit Type

- ()
  - Looks like an empty tuple
  - Is a type of its own
  - It’s purpose is to be “useless”
- Everything in Rust is an expression
  - Similar to many functional languages
- A function without return type returns it
  - Similar to void in C/C++