

CMSC 330: Organization of Programming Languages

Structs and Enums in Rust

Rust Data

- So far, we've seen the following kinds of data
 - Scalar types (int, float, char, string, bool)
 - Tuples, Arrays, and Collections
- How can we build other data structures?
 - Structs (like Objects; support for methods)
 - Enums (like Ocaml Data Types)

Structs: Definitions & Construction

```
struct Rectangle {  
  width: u32,      Field with int type  
  height: u32,  
}  
  
fn main() {  
  // construction  
  let rect1 = Rectangle { width: 30, height: 50 };  
  // accessing fields  
  println!("rect1's width is {}", rect1.width);  
}
```

Construction

Field accessing

Prints **rect1's width is 30**

Structs: Printing

```
struct Rectangle{
    width:u32,
    height:u32,
}

fn main() {
    let rect1 = Rectangle { width:30, height:50};
    println!("rect1 is {}", rect1);
}
```

error[E0277]: the trait bound `Rectangle: std::fmt::Display` is not satisfied

Structs: Printing with Derived Traits

```
#[derive(Debug)]
```

Derive printing format

```
struct Rectangle{  
    width:u32,  
    height:u32,  
}
```

Use printing format

```
fn main() {  
    let rect1 = Rectangle { width:30, height:50};  
    println!("rect1 is {:?}", rect1);  
}
```

Prints `rect1 is Rectangle { width: 30, height: 50 }`

Structs

- Syntax

- `struct T [$\langle T \rangle$] { $n1:t1$, ..., $ni:ti$, }`
- the ni are called **fields**, begin with a lowercase letter
- [$\langle T \rangle$] optionally for generics (see later)

- Evaluation

- **Construction:**

T { $n1:v1$, ..., $ni:\underline{vi}$ } is a value if vi are values.

- **Destruction:**

$t.ni$ returns the ni field of t

- Type Checking

- T { $n1:v1$, $ni:vi$ } : T if vi has type ti

Methods: Definitions on Structs

Self argument of type Rectangle

```
impl Rectangle {  
  fn area(&self) -> u32 {  
    self.width * self.height  
  }  
}
```

`impl Rectangle` defines an implementation block

- `self` arg has type `Rectangle` (reference)
- same ownership rules:
 - `&self` for borrowing,
 - `self` to take ownership,
 - `&mut self` to allow mutation

Methods: Calls

```
fn main() {  
  let rect1 = Rectangle { width:30, height:50 };  
  println!("The area is {} pixels.",  
    rect1.area())  
}
```

dot syntax to call methods

If method had arguments, use function call e.g.,
`rect1.area(3)`

Methods: Many Arguments

```
impl Rectangle {  
  fn can_hold(&self, other:&Rectangle) -> bool {  
    self.width > other.width && self.height > other.height  
  }  
  
  fn square(size:u32) -> Rectangle {  
    Rectangle { width: size, height: size }  
  }  
}
```

`square` is called an **Associated Method**

- no self argument
- operates on Rectangles
- called with `let sq = Rectangle::square(3);`

Generic Lifetimes

```
struct ImportantExcerpt<'a> {  
    part: & 'a str,  
}  
  
fn main() {  
    let novel =String::from("Generic Lifetime");  
    let i = ImportantExcerpt { part: &novel; }  
}
```

When structs hold **references**, we need to add a lifetime annotation on **every** reference in the struct's definition.

Lifetimes in Methods

```
struct ImportantExcerpt<'a> {  
    part: & 'a str,  
}  
  
impl<'a> ImportantExcerpt<'a> {  
    fn level(&self) -> i32 {  
        3  
    }  
}
```

Implementation needs lifetime annotation.

Lifetime is inferred in function (using **elision**^[*]).

[*] <https://doc.rust-lang.org/book/second-edition/ch10-03-lifetime-syntax.html#lifetime-elision>

Quiz 1: `point` is immutable at *HERE*

```
struct Point {  
    x: i32,  
    y: i32,  
}  
let mut point = Point { x: 0, y: 0 };  
point.x = 5;  
let point = point;  
// HERE
```

- A. True
- B. False

Quiz 1: `point` is immutable at *HERE*

```
struct Point {
  x: i32,
  y: i32,
}
let mut point = Point { x: 0, y: 0 };
point.x = 5;
let point = point;
// HERE
```

- A. True.
- B. False

Mutability is a property of the binding;
the old `point`'s contents are copied to
the new one

Enums

```
enum IpAddr{  
  V4(String),  
  V6(String),  
}
```

definition

```
let home = IpAddr::V4(String::from("127.0.0.1"));  
let loopback = IpAddr::V6(String::from("::1"));
```

construction

Like Variants in Ocaml

```
type IpAddr = V4 of string | V6 of string ;;  
let home = V4 "127.0.0.1";;  
let loopback = V6 "1";;
```

Enums with Blocks

```
enum IpAddr{
  V4(String),
  V6(String),
}

impl IpAddr {
  fn call(&self) {
    // method body would be defined here
  }
}

let m = IpAddr ::V6(String::from("::1"));
m.call();
```

Enums with Structs

Like in OCaml, enums might contain any type, e.g., structs, references, ...

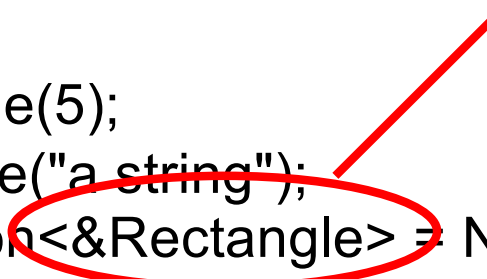
```
struct Ipv4Addr{  
  // details elided  
}  
  
struct Ipv6Addr{  
  // details elided  
}  
  
enum IpAddr{  
  V4(Ipv4Addr),  
  V6(Ipv6Addr),  
}
```


The Option Enum: Generic Types

Defined in standard lib

```
enum Option<T> { Some(T), None, }  
  
let some_number = Some(5);  
let some_string = Some("a string");  
let absent_number: Option<&Rectangle> = None;
```

Instantiation with
any type!



Compare with OCaml

```
type 'a Option = Some of 'a | None ;;  
  
let some_number = Some 5 ;;  
let some_string = Some "a string" ;;  
val absent_number :: int option ;;  
let absent_number = None;;
```

Generics in Structs & Methods

Generic **T** in struct

```
struct Point<T> {  
    x: T,  
    y: T,  
}
```

Generic **T** in methods

```
impl<T> Point<T> {  
    fn x(&self) -> &T {  
        &self.x  
    }  
}
```

Instantiate **T** as **i32**

```
fn main() {  
    let p = Point { x:5, y:10};  
    println!("p.x = {}", p.x());  
}
```

Matching

```
fn plus_one(x:Option<i32>) -> Option<i32> {  
  match x {  
    Some(i) => Some(i + 1),  
    None => None,  
  }  
}
```

Matching should be exhaustive!

```
fn plus_one(x:Option<i32>) -> Option<i32> {  
  match x {  
    Some(i) => Some(i + 1),  
  
  }  
}
```

Error at compile time!

error[E0004]: non-exhaustive patterns:

`None` not covered

Enums

- Syntax

- `enum T [<T>] { C1 [(t1)], ..., Cn [(tn)], }`
- the *C_i* are called constructors
 - Must begin with a capital letter; may include associated data notated with brackets [] to indicate it's optional

- Evaluation

- A constructor *C_i* is a value if it has no assoc. data
 - *C_i(v_i)* is a value if it does
- Destructing a value of type *t* is by pattern matching
 - patterns are constructors *C_i* with data components, if any

- Type Checking

- `Ci [(vi)] : T [if vi has type ti]`

Quiz 2: Output of following code

```
enum Number {
    Zero,
    One,
    Two,
}
use Number::Zero;
let t = Number::One;
match t {
    Zero=> println!("0"),
    Number::One => println!("1"),
}
```

- A. 0
- B. 1
- C. Compile Error

Quiz 2: Output of following code

```
enum Number {
    Zero,
    One,
    Two,
}
use Number::Zero;
let t = Number::One;
match t {
    Zero=> println!("0"),
    Number::One => println!("1"),
}
```

A. 0

B. 1

C. Compile Error. Pattern `Two` not covered

If-let, for non exhaustive matches

```
fn check(x: Option<i32>) {  
  if let Some(42) = x {  
    println!("Success!") // only executed if the match succeeds  
  } else {  
    println!("Failure!")  
  }  
}
```

```
fn main (){  
  check(Some(3));; // prints "Failure!"  
  check(Some(42));; // prints "Success!"  
  check(None);; // prints "Failure!"  
}
```


Recap: Structs and Enums

1. Structs define data structures with fields
 - And implementation blocks collect methods on to specify the behavior of structs (like objects)
2. Enums define a set of possible data types
 - Like OCaml variant types
 - Use match or if-let to deconstruct