CS 241: Systems Programming Lecture 10. Compound types and Loops

Fall 2025

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Compound types

Compound types group multiple values together

- Tuples
- Arrays
- Structures (we'll get to these later)
- Enumerations (we'll get to these later)

Tuples

Tuples let us group multiple, heterogeneous types together

They have fixed size (no adding or removing elements)

```
let val: (i32, char, f64) = (42, '🦀', 6.022e23);
```

Tuples can be built from any types

Accessing elements of the tuple

Use `.0`, `.1`, `.2`, etc. to access fields

```
let val: (i32, char, f64) = (42, '🦀', 6.022e23);
let num = val.0;
let ch = val.1;
let float = val.2;
```

Destructuring tuples

```
let val: (i32, char, f64) = (42, '🦀', 6.022e23);
let (num, ch, float) = val;
```

Does what you want: assigns 42 to `num`, 🦀 to `ch`, and 6.022e23 to `float`

Tuples in parameters

```
/// Compute the Euclidean distance between p1 and p2
fn distance(p1: (f64, f64, f64), p2: (f64, f64, f64)) -> f64 {
    let (x1, y1, z1) = p1;
    let (x2, y2, z2) = p2;
    let dx = x1 - x2;
    let dy = y1 - y2;
    let dz = z1 - z2;

    (dx * dx + dy * dy + dz * dz).sqrt()
}

fn main() {
    let p1 = (1.2, -8.6, 3.0);
    let p2 = (-10.2, -9.3, -6.1);
    println!("Distance = {}", distance(p1, p2))
}
```

Returning tuples

```
fn origin() -> (f64, f64, f64) {
    (0.0, 0.0, 0.0)
}
```

Printing tuples

Printing tuples

```
fn main() {
    let p1 = (1.2, -8.6, 3.0);
    let p2 = (-10.2, -9.3, -6.1);
    println!("|{p1} - {p2}| = {}", distance(p1, p2));
}
```

Printing tuples

```
fn main() {
    let p1 = (1.2, -8.6, 3.0);
    let p2 = (-10.2, -9.3, -6.1);
    println!("|{p1} - {p2}| = {}", distance(p1, p2));
}
```

```
error[E0277]: `(f64, f64, f64)` doesn't implement `std::fmt::Display`
  --> compoundtypes.rs:30:16
   |
30 |     println!("|{p1} - {p2}| = {}", distance(p1, p2))
   |                ^^^^ `(f64, f64, f64)` cannot be formatted with the default formatter
   |
   = help: the trait `std::fmt::Display` is not implemented for `(f64, f64, f64)`
   = note: in format strings you may be able to use `{:?}` (or {:#?} for pretty-print)
instead
```

Printing tuples' Debug representations

```
fn main() {
    let p1 = (1.2, -8.6, 3.0);
    let p2 = (-10.2, -9.3, -6.1);
    println!("|{p1:?} - {p2:?}| = {}", distance(p1, p2));
}

Output:
|(1.2, -8.6, 3.0) - (-10.2, -9.3, -6.1)| = 14.603424255975035
```

```
let val: (String, bool) = (String::from("clickers"), true);
```

how do we access the boolean component of `val`?

A. `val.1`

B. `val.2`

C. `val.bool`

D. `val.true`

E. `val.clickers`

Modifying tuple components

Modifying tuple components

```
fn main() {
    let mut val: (String, bool) = (String::new(), false);
    println!("{val:?}");

    val.0.push_str("Rust is great!");
    val.1 = true;

    println!("{val:?}");
}
```

Modifying tuple components

```
fn main() {
    let mut val: (String, bool) = (String::new(), false);
    println!("{val:?}");

    val.0.push_str("Rust is great!");
    val.1 = true;

    println!("{val:?}");
}
```

```
Output:
("", false)
("Rust is great!", true)
```

Unit—a zero-element tuple

There's zero-element tuple called **unit** which we write as `()`

The `()` type has exactly one value: `()`

```
let unit: () = ();
```

Or just

```
let unit = ();
```

This is often used with a `Result<(), E>` when a function has no meaningful value on success, but might return an error

Unit—a zero-element tuple

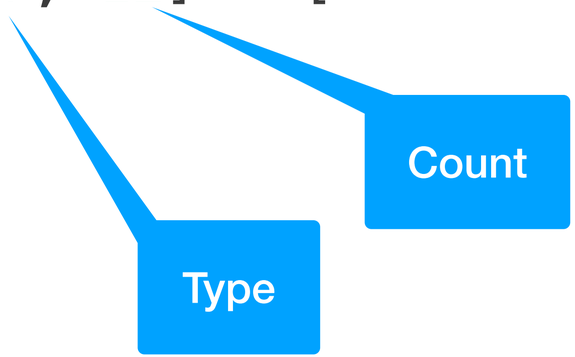
```
fn could_error() -> Result<(), String> {
    // ...
    if some_error_condition {
        return Err(String::from("Some error"));
    }

    Ok(())
}
```

This returns () wrapped in an Ok

Arrays

Arrays let us group multiple values of a **single type** together in a **fixed-size** structure

```
let months: [&str; 12] = [
    "January",
    "February",
    "March",
    "April",
    "May",
    "June",
    "July",
    "August",
    "September",
    "October",
    "November",
    "December",
];
```



Accessing array elements

Standard array access notation: `arr[index]`

```
println!("{}", months[5]);
let idx: usize = 8;
println!("{}", months[idx]);
println!("{}", months[idx + 1]);
```

Accessing array elements

The type of the index must be a **usize**

```
let idx: i32 = 8;
println!("{}", months[idx]);
```

```
error[E0277]: the type `[&str]` cannot be indexed by `i32`
  --> compoundtypes.rs:60:27
   |
60 |     println!("{}", months[idx]);
   |                           ^^^ slice indices are of
type `usize` or ranges of `usize`
   |
```

Discussion question: why must the index array be a usize?

Integer types
- Signed integer types (can be negative): `i8`, `i16`, `i32`, `i64`, `i128`
  - Equivalent to Java's `byte`, `short`, `int`, and `long`
  - i32 is the default when not specified
- Unsigned integer types (only nonnegative): `u8`, `u16`, `u32`, `u64`, `u128`

Platform-dependent integer types
- `usize`: 32-bit or 64-bit unsigned integer
  - Used as an index or as a count of items in a collection
- `isize`: signed version of `usize`

A. Click any letter when done

Casting i32 to usize

Casting i32 to usize

The type of the index must be a usize

```
let idx: i32 = 8;
println!("{}", months[idx as usize]);
```

Must be careful: negative numbers wrap around to large positive numbers

```
let idx: i32 = -8;
```

Casting i32 to usize

The type of the index must be a usize

```
let idx: i32 = 8;
println!("{}", months[idx as usize]);
```

Must be careful: negative numbers wrap around to large positive numbers

```
let idx: i32 = -8;
println!("{}", months[idx as usize]);
```

```
error: this operation will panic at runtime
  --> compoundtypes.rs:60:20
   |
60 |     println!("{}", months[idx as usize]);
   |                     ^^^^^^^^^^^^^^^^^^^^ index out of bounds: the
length is 12 but the index is 18446744073709551608
   |
```

Rust prevents out-of-bounds access

Error at compile time, if the compiler can prove the index is out of bounds (as on the previous slide)

At run time, otherwise:

```
thread 'main' panicked at 'index out of bounds: the len
is 12 but the index is 12'
```

Creating an array by copying an element

```
    let arr: [i64; 20] = [42; 20];
    println!("{arr:?}");
```

```
Output:
[42, 42, 42, 42, 42, 42, 42, 42, 42, 42, 42, 42, 42, 42, 42,
42, 42, 42, 42, 42]
```

Which of the following is the correct syntax to create an array of 5 u32 integers with values 1, 2, 3, 4, and 5?

A. `let arr: [u32; 5] = [1..5];`

B. `let arr: [5; u32] = [1, 2, 3, 4, 5];`

C. `let arr = [1, 2, 3, 4, 5];`

D. `let arr: [5; u32] = [1..5; 5];`

E. `let arr: [u32; 5] = [1, 2, 3, 4, 5];`

Vectors

Vectors are growable arrays (like ArrayList in Java or a list in Python)

```
let mut v: Vec<String> = Vec::new();
v.push(String::from("Hi"));
v.push(String::from("there!"));
println!("{v:?}");
```

```
Output:
["Hi", "there!"]
```

Accessing elements

Access elements just like you would an array

```
    println!("{} {}", v[0], v[1]);
```

```
Output:
Hi there!
```

Getting the length of a Vec

Use the len() method

```
let mut v: Vec<String> = Vec::new();
println!("{}", v.len());
v.push(String::from("Hi"));
println!("{}", v.len());
v.push(String::from("there!"));
println!("{}", v.len());
```

```
Output:
0
1
2
```

Create a vector with some elements

To create a vector with some elements, use `vec![]`

```
let v: Vec<i32> = vec![1, 2, 3, 4, 5];
```

To make it mutable, use `let mut` as usual

Loop

```
fn main() {
    let mut n = 17;
    loop {









    }
    println!();
}
```

Loop

```
fn main() {
    let mut n = 17;
    loop {
        print!("{n} ");
        if n == 1 {
            break;
        }




    }
    println!();
}
```

Loop

```
fn main() {
    let mut n = 17;
    loop {
        print!("{n} ");
        if n == 1 {
            break;
        }
        if n % 2 == 0 {
            n = n / 2;
        } else {
            n = 3 * n + 1;
        }
    }
    println!();
}
```

Loop

```
fn main() {
    let mut n = 17;
    loop {
        print!("{n} ");
        if n == 1 {
            break;
        }
        if n % 2 == 0 {
            n = n / 2;
        } else {
            n = 3 * n + 1;
        }
    }
    println!();
}
Output: 17 52 26 13 40 20 10 5 16 8 4 2 1
```

While loop

```
fn main() {
    let mut n = 17;
    while n != 1 {
        print!("{n} ");
        if n % 2 == 0 {
            n = n / 2;
        } else {
            n = 3 * n + 1;
        }
    }
    println!("1");
}
```

Looping over a vector (or array) by index

```
fn main() {
    let v: Vec<i32> = vec![1, 2, 3, 4, 5];
    let mut idx = 0;
    while idx < v.len() {
        println!("v[{idx}] = {}", v[idx]);
        idx += 1;
    }
}
Output:
v[0] = 1
v[1] = 2
v[2] = 3
v[3] = 4
v[4] = 5
```

Loop over a collection

We can use a for loop (similar to Python's for loop)

```
fn main() {
    let v: Vec<i32> = vec![1, 2, 3, 4, 5];

    for num in v {
        println!("{num}");
    }
}
```

The for loop takes ownership of the vector!

```
    for num in v {
        println!("{num}");
    }
    for num in v {
        println!("{num}");
    }
error[E0382]: use of moved value: `v`
   --> compoundtypes.rs:106:16
    |
101 |     let v: Vec<i32> = vec![1, 2, 3, 4, 5];
    |         - move occurs because `v` has type `Vec<i32>`, which does not
implement the `Copy` trait
102 |
103 |     for num in v {
    |                - `v` moved due to this implicit call to `.into_iter()`
...
106 |     for num in v {
    |                ^ value used here after move
```

Quick fix

```
for num_ref in &v {
    println!("{num_ref}");
}
for num in v {
    println!("{num}");
}
```

By using &v, we're saying loop over a reference to v, this does not consume v so we can use it again later

When we loop over a reference, the variable is bound to a reference to the elements, rather than being the elements themselves (more about refs later!)

Loop over a collection with index

We can use a for loop (similar to Python's for loop)

```
fn main() {
    let v: Vec<i32> = vec![1, 2, 3, 4, 5];

    for (idx, num) in v.iter().enumerate() {
        println!("v[{idx}] = {num}");
    }
}
```

`v.iter()` returns an iterator over references to elements

`.enumerate()` returns an iterator over pairs `(index, element)`

Wed Preview - Memory Safety

- How does Rust implement memory safety?
  - Ownership
  - Stack/heap
  - Pointers