**Rust Quick Reference**

1. **Overview**

**1.1 Characteristics**

* Precompiled just like C.
* zero-cost abstractions: higher-level features that compile to lower-level code as fast as code written manually.
* Includes the official building system & packet manager **Cargo**, allowing the user to control and build dependencies.
* Snake case as the conventional style for function and variable names. In snake case, all letters are lowercase and underscores separate words. E.g. variable\_name;

**1.2 Developer tools in Rust**

* **Cargo**: the included dependency manager and build tool, makes adding, compiling, and managing dependencies painless and consistent across the Rust ecosystem.

Cargo has a mechanism that ensures you can rebuild the same artifact every build (Cargo.TOML). Cargo will use only the versions of the dependencies you specified until you indicate otherwise. To ignore manual versions, use cargo update which will update dependencies to latest versions.

* **Rustfmt**: ensures a consistent coding style across developers.
* The Rust **Language Server**: powers Integrated Development Environment (IDE) integration for code completion and inline error messages.
* **Crate**: collection of Rust source code files (Basically a library).
* The ***Prelude*** is a list of functionalities that Rust imports into every program, it includes traits of fundamental types, destructors and overloading, heap allocation, ownership, clone, comparison traits, generic conversions, iterators, heap allocated strings and vectors.

**1.3 Fields on Rust**

Command line tools, web services, DevOps tooling, embedded devices, audio and video analysis and transcoding, cryptocurrencies, bioinformatics, search engines, Internet of Things applications, machine learning, and even major parts of the Firefox web browser.

1. **Rust Fundamentals**
   1. **Variables**

let -> Creates a variable.

**{}**  -> Curly brackets are the format specifiers (called % in C) of Rust. In Rust they are just a place holder.

E.g. println! ("x = {} and y = {}", x, y);

**Conversion**

Rust will not automatically try to convert non-Boolean types to a Boolean, it must be explicit and provide a Boolean value for safety. Note that if doesn’t require parenthesis.

E.g. let number = 3;

if number { println!("number was three"); }//expected bool, found integer

2.1.1 Data Types

Rust is a statically typed language, which means that it must know the types of all variables at compile time. The compiler can usually infer what type we want to use based on the value and how we use it. In cases when many types are possible, such as when we converting a String to a numeric type using parse, we must add a type annotation.

E.g. let number = 13; //implicit data type

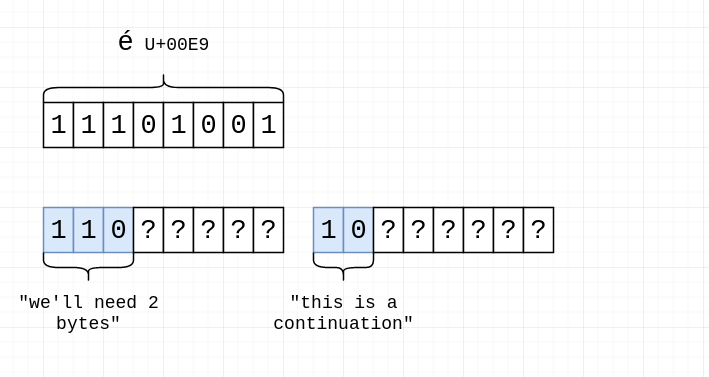
let number: i32 = 13; //explicit data type

|  |  |  |
| --- | --- | --- |
| **Integer Types** | | |
| **Length** | **Signed** | **Unsigned** |
| 8-bit | i8 | u8 |
| 16-bit | i16 | u16 |
| 32-bit | i32 | u32 |
| 64-bit | i64 | u64 |
| 128-bit | i128 | u128 |
| arch | isize | usize |

Rust’s **char** type is always 4 bytes in size as it represents a Unicode Scalar Value, which means it can represent a lot more than just ASCII like emojis. However not always the 4 bytes have information. In unicode encoding, the highier part indicate the #ofBytes needed to store the symbol ranging from 2 to 4 bytes:

* If a byte starts with 110 it means we'll need two bytes
* If a byte starts with 1110 it means we'll need three bytes
* If a byte starts with 11110 it means we'll need four bytes
* If a byte starts with 10, it means it's a continuation of a multi-byte character sequence.

The following example encodes “é” by using 2 bytes(right align), leftover bits are filled with 0 (called padding).



F2.1.1.1. Encoding “é” in unicode

2.1.2 Arrays vs Vectors

Arrays are useful when you want your data allocated on the stack rather than the heap or when you want to ensure you always have a fixed number of elements. E.g. let a: [i32; 5] = [1, 2, 3, 4, 5]; //array with type

An array isn’t as flexible as the vector type, though. A vector is a similar collection type provided by the standard library that is allowed to grow or shrink in size

**Tuple**

A tuple is a general way of grouping together a number of values with a variety of types into one compound type. Tuples have a fixed length: once declared, they cannot grow or shrink in size.

E.g. let tup: (i32, f64, u8) = (500, 6.4, 1);

**Shadowing:** Shadowing lets us reuse variables with same name, rather than forcing us to create two unique variables. The second variable’s value is what appears when the variable is used. It’s also possible to change the type of the variable since we’re effectively creating a new variable. E.g. let x = 5; let x = x + 1; // x=6

* 1. **Traits**

--**mut**: Assigns mutable (modifiable, non-static content) attribute. In Rust variables are **immutable** by **default** in order to enforce safety and easy concurrency. E.g.: let mut guess = 5;

--**match:** allows us to compare a value against a series of patterns and then execute code based on which pattern matches. E.g. comparing returns an Ordering enum with 3 possible values: Less, Greater, Equal. Note that match is exhausting so all cases must be handled ( in case you want to handle remaining cases “\_” place holder is a useful to match any pattern )

match number1.cmp(&number2) {

Ordering::Less => println!("Number 1 is smaller"),

Ordering::Greater => println!("Number 1 is larger!"),

\_ => (), //The \_ pattern will match any value.

--**const**: constants are ALWAYS immutable. Furthermore, constants require annotated type and can only be set to a constant expression computed in compile time. const MAX\_POINTS: u32 = 100\_000;

* 1. **Compiling**

|  |  |
| --- | --- |
| Instruction | Description |
| Cargo new {name} | Generates the packet manager folder for Cargo to manage your rust project |
| Cargo build  --release  --target {TRIPLET} | Compiles rust program.  - Compiles with optimizations (superfast code however is slower compilation time)  - Compiles for a target denoted by the TRIPLET. E.g. thumbv7m-none-eabi |
| ./target/debug/{Cargo\_File} | Creates executable of the cargo project on the target |
| Cargo run |  |
| Cargo check | Check correct compiling without producing an executable (speed-up the process) |
| Use | Import library |
| cargo readobj --bin {project} -- -file-headers | can print the ELF headers to confirm that this is an ARM binary |
| Cargo-size --bin {project} --release -- -A | can print the size of the linker sections of the binary. |

Figure 2.3.1 Compiling your project

* 1. **Input/output**

println!() -> Macro to print a string on screen.

* 1. **Strings**

The String type is the most common type that has ownership over the contents of the string. Growable and UTF-8 encoded.

* 1. **Functions & Methods**

**Functions**

Rust doesn’t care where you define your functions, only that they’re defined somewhere (unlike C, where you must define a function before use it).

In function signatures, you must declare the type of each parameter, this means in the annotated form. E.g. fn example\_function(x: i32, y: i32){

println!(“value of x is: {}”, x) …}

**Functions with returning values:**

Return type goes after an arrow (**->**). Functions can return early by using the return keyword and specifying a value, but most functions return the last expression implicitly, by not adding semicolon (this means that this is the return value).

fn plus\_one(x: i32) **->** i32 { x + 1 } //no semicolon on x + 1

plus\_one(5); //6

**Methods**

**object::method**() -> ´´method´´ is an associated function of an object type (static method).

E.g.: let guess = String::new(); //method that creates a new instance of a String

instance::method.submethod() -> Calls sub-method on method handle. E.g.: io::stdin().read\_line();

* 1. **Failures**

Result types are enumerations. For Result, the variants are Ok or Err. The Ok variant indicates the operation was successful, and inside Ok is the successfully generated value. The Err variant means the operation failed and Err contains information about how or why the operation failed. The purpose of these Result types is to encode error-handling information.

E.g.: .expect(“failed”) -> Expect Unwraps a result, yielding the content of an [Ok](https://doc.rust-lang.org/std/result/enum.Result.html" \l "variant.Ok). Otherwise panics and includes message and content of Err.

* 1. **Scope {}**
  2. **Loops**

|  |  |  |
| --- | --- | --- |
| **For** | **While** | **Loop** |
| Increased safety of the code and eliminated the chance of bugs that might result from going beyond the end of the array or not going far enough and missing some items. | Useful to evaluate a condition within a loop. However, is slower because the compiler adds runtime code to perform the conditional check on every element on every iteration through the loop. | Executes a block of code over and over again forever or until you explicitly tell it to stop. |

1. **Stack & Heap**

**Stack-allocated data has a known, fixed size**. Data with an **unknown size at compile time or a size that might change must be stored on the heap instead.** The heap is less organized: when you put data on the heap, you request a certain amount of space. The operating system finds an empty spot in the heap that is big enough, marks it as being in use, and returns a pointer, which is the address of that location. This process is called allocating on the heap and is sometimes abbreviated as just allocating. Pushing values onto the stack is not considered allocating. Because the pointer is a known, fixed size, you can store the pointer on the stack, but when you want the actual data, you must follow the pointer.

1. **Ownership**

All programs have to manage the way they use a computer’s memory while running. Some languages have garbage collection that constantly looks for no longer used memory as the program runs; in other languages, the programmer must explicitly allocate and free the memory. Rust uses a third approach: memory is managed through a system of ownership with a set of rules that the compiler checks at compile time. None of the ownership features slow down your program while it’s running.

### 4.1 [Ownership Rules](https://doc.rust-lang.org/book/ch04-01-what-is-ownership.html" \l "ownership-rules)

* Each value in Rust has a **variable** that’s called its **owner**.
* There can only be **one** owner at a time.
* When the **owner** goes **out of scope**, the value will be dropped hence the memory is freed.

Note: Ownership rules applies to variable as well as functions.

**4.2 Interacting with data: Move if Heap, Copy if Stack,**

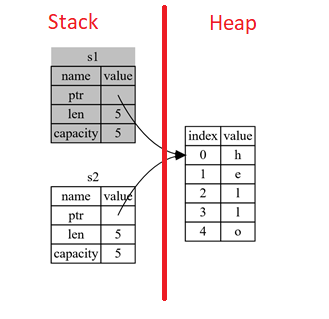
Rust will never automatically create “deep” copies of your heap allocated data. Instead Rust performs a “move” operation, on which:

* Stack-allocated Data is Copied with an internal clone.
* Heap-allocated Data copies just the reference to the same location.
* Previous variable is **invalidated.**

This way, the previous owner will not try to drop memory when goes out of scope because it’s invalid; the new owner will now oversee the value dropping. In the next example, known size values like length and capacity are stored on the Stack so they are copied and dynamic values like String data is allocated on heap so only the pointer is copied as shown on F4.1.1.

let s1 = String::from("hello"); //String stores some values on **Heap** and some on **Stack**

let s2 = s1; //s1 is now invalid for safety. Now S2 has ownership



F4.1.1 Representation in memory after s1 has been invalidated.

|  |  |
| --- | --- |
| Ownership in functions | |
| Pass **copy** | Pass **ownership** |
| // x is created on stack  let x = 5;  // x (i32) is Copied into function  makes\_copy(x);  //x is still valid here | // s is created on the heap  let s = String::from("hello");  //s pass ownership to the function...  take\_ownership(s);  //s is no longer valid here |

1. **Reference (&) and borrowing**

**& ->** Get memory address: operator that gets the memory address (in hexadecimal) of a piece of data.

**5.1 The Rules of References**

* At any given time, you can have *either* one mutable reference *or* any number of immutable references.
* References must always be valid.

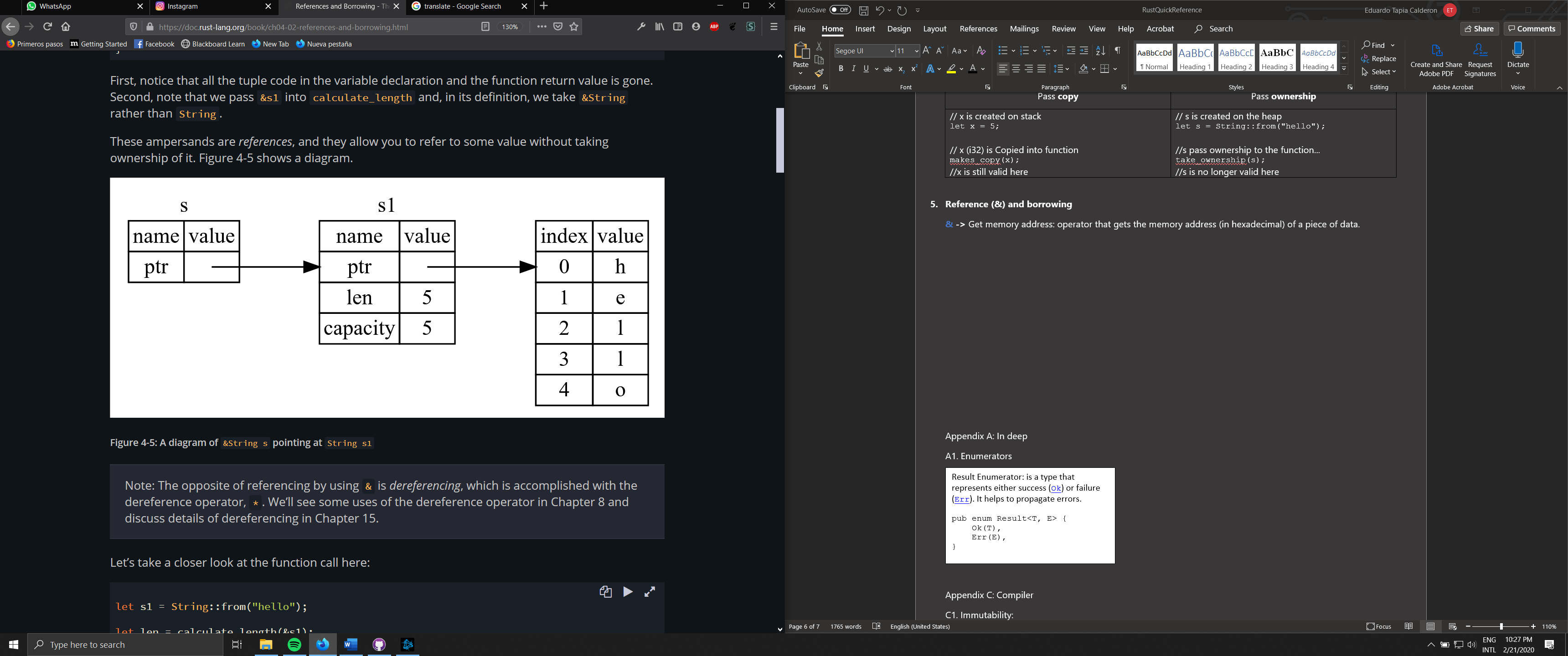
**5.2 Borrowing**

It’s also possible to use a value without taking ownership, by using references (&), we call having references as function parameters **borrowing**. The scope in which the variable is valid isn’t affected by the borrowing variable/function, so we don’t have to drop what the reference points to when it goes out of scope because we **didn’t had ownership** in the first place.

let s1 = String::from("hello");

let len = calculate\_length(&s1);

fn calculate\_length(s: &String) -> usize { s.len()}



5.1.1 Function borrowing variable s1

**5.3 Mutable references**

Note that references are immutable by default, to create a mutable reference, just add &mut s trait.

A big restriction on mutable references is that you can have **only ONE mutable reference** to a value in the **same scope** also is not possible to have mutable and immutable references in the same scope. This restriction allows mutation in a very controlled fashion, avoiding race conditions, simultaneous access to the same piece of data, synchronization problems and sudden changes.

**5.4 Dangling references**

if you have a reference to some data, the compiler will ensure that the data will not go out of scope before the reference to the data does, at compile time!.

**5.5 Slice Type**

Slices let you reference a contiguous sequence of elements in a collection rather than the whole collection. Slice method from in String tracks a starting and an ending index. E.g.

let s = String::from("hello world");

let hello = &s[0..5];

let world = &s[6..11];

**Slice Program:** write a function that takes a string and returns the first word it finds in that string

fn first\_word(s: &String) -> &str {

let bytes = s.as\_bytes();

for (i, &item) in bytes.iter().enumerate() {

if item == b' ' {

return &s[0..i]; } }

&s[..] }

**5.6 Two types of strings: String vs %str**

https://fasterthanli.me/blog/2020/working-with-strings-in-rust/

1. **Structures**

Similar to tuples, structures can group many data types together. However structures doesn´t rely on of data declaration.

struct User {

username: String,

email: String,

sign\_in\_count: u64,

active: bool,

}

**Instance**

Instances are declared using key:value pairs, Luckily there is a shorthand notation when variables and fields have the same Name (email: email -> email). Access to a specific field is granted through dot notation. Entire instance should be mutable, Rust does´t allow to mark only certain fields as mutable.

fn build\_user(email: String, username: String) -> User {

User {

email,

username,

active: true,

sign\_in\_count: 1,

}

}

**Struct update syntax**

It is possible to create a new instance that uses values of an existing one. And there is also a shorthand notation presented on the remaining fields with “..” .

let user2 = User {

email: user1.email,

username: user1.username,

..user1

};

**6.1 Tuple structure**

Tuple structs have the added meaning the struct name provides but don’t have names associated with their fields.

struct 3DPoint(i32, i32, i32);

let origin = 3DPoint(0, 0, 0);

**6.2 Methods**

Methods are different from functions only in that they’re defined within the context(impl) of the struct and their first parameter is always self, which represents the instance of the struct the method is being called on.

impl Rectangle {

fn area(&self) -> u32 {

self.width \* self.height

}

}

**6.3 Associated functions**

We’re allowed to define functions within impl blocks that don’t take self as a parameter, these are called **associated functions**(still functions, not methods)**.** Associated functions are often used for constructors that will return a new instance of the struct. To call this associated function, use the “::” notation. E.g.

impl Rectangle {

fn square(size: u32) -> Rectangle { //no self

Rectangle { width: size, height: size }

}

}

let sq = Rectangle**::**square(3);

**6.4 Derived traits**

The println! macro can do many kinds of formatting, and by default, the curly brackets tell println! to use formatting known as Display (output intended for direct end user consumption). For primitive types we’ve seen so far there’s only one way you’d want to show them. But with structs, the way println! should format the output is less clear because there are more display possibilities: Do you want commas or not? Do you want to print the curly brackets? Should all the fields be shown? Due to this ambiguity, Rust doesn’t try to guess what we want, and structs don’t have a provided implementation of Display.

println!("rect1 is {**:?**}", rect1);. Putting the specifier **:?** inside the curly brackets tells println! we want to use an output format called Debug. The **Debug trait** enables us to print our struct in a way that is useful for developers so we can see its value while we’re debugging our code.

Rust does include functionality to print out debugging information, but we have to explicitly make that functionality available for our struct. To do that, we add the annotation #[derive(Debug)] just before the struct definition.

#[derive(Debug)]

struct Rectangle {

width: u32,

height: u32,

}

fn main() {

let rect1 = Rectangle { width: 30, height: 50 };

println!("rect1 is {:?}", rect1);

}

**6.5 Where’s the -> Operator?**

In C and C++, two different operators are used for calling methods: you use “.” if you’re calling a method on the object directly and -> if you’re calling the method on a pointer to the object and need to dereference the pointer first. In other words, if object is a pointer, object->something() is similar to (\*object).something().

Rust doesn’t have an equivalent to the -> operator; instead, Rust has a feature called **automatic referencing and dereferencing**. Here’s how it works: when you call a method with object.something(), Rust automatically adds in &, &mut, or \* so object matches the signature of the method. In other words, the following are the same: p1.distance(&p2); or (&p1).distance(&p2);

1. **Enums and pattern matching**

Enumerators allow us to enumerate all possibilities but only choosing one. It has some properties of structs as all variants should be treated as the same type.

|  |  |
| --- | --- |
| Simple Enum and usage | Data embedded in the Enum |
| enum IpAddrKind {  V4,  V6,  } | enum IpAddr {  V4(u8, u8, u8, u8),  V6(String),  } |
| let four = IpAddrKind::V4;  let six = IpAddrKind::V6;  \*Note that the variants of the enum are namespaced under its identifier, allowing either: V4 or V6.  fn route(ip: IpAddrKind) { } | let home = IpAddr::V4(192, 168, 50, 1);  let loopback = IpAddr::V6(String::from("::1")); |

**Using methods and associated functions on Enums**

Just as we’re able to define methods on structs using impl, we’re also able to define methods on enums. E.g.

enum Message {

Quit,

Move { x: i32, y: i32 },

Write(String),

ChangeColor(i32, i32, i32),

}

impl Message {

fn call(&self) {

// method body would be defined here

}

}

let m = Message::Write(String::from("hello")); //::Write is namespaced in Message enum

m.call();

**7.1 Option enum vs Null**

The concept that null is trying to express is a useful one: a null is a value that is currently invalid or absent for some reason. Despite being implemented poorly on C, where a null has led to innumerable errors, vulnerabilities, and system crashes. The problem with null values is that if you try to use a null value as a not-null value, you’ll get an error of some kind. Because this null or not-null property is pervasive, it’s extremely easy to make this kind of error.

The problem radicates on the implementattion. Rust **does not have nulls**, but it does have an enum that can encode the concept of a value being present or absent. This enum is Option<T>, and it is defined by the standard library(prelude) as follows:

enum Option<T> {

Some(T),

None,

}

let some\_string = Some("a string"); //presence

let absent\_number: Option<i32> = None; //abscense

Option is better than Null because Option<T> and T (where T can be any type) are different types, the compiler won’t let us use an Option<T> value as if it were definitely a valid value. In order to use an Option<T> value, you want to have code that will handle each variant of Option Enum.

let y: Option<i8> = Some(5);

let sum = 8 + y; //Will not compile. Needs to handle Option<i8> Enum

\*Option is strong with match to handle cases

**7.2 if-let**

If let allows us to combine if and let into a less verbose way to handle values that match one pattern while ignoring the rest. Using if let means less typing, less indentation, and less boilerplate code. However, you lose the exhaustive checking that match enforces

|  |  |
| --- | --- |
| Verbose matching pattern, only 1 case is useful | Shorthand if let, handles neatly 1 pattern |
| let some\_u8\_value = Some(0u8);  match some\_u8\_value {  Some(3) => println!("three"),  \_ => (),  } | if let Some(3) = some\_u8\_value {  println!("three");  } |

Appendix A: In deep

A1. Enumerators

Result Enumerator: is a type that represents either success ([Ok](https://doc.rust-lang.org/std/result/enum.Result.html" \l "variant.Ok)) or failure ([Err](https://doc.rust-lang.org/std/result/enum.Result.html" \l "variant.Err)). It helps to propagate errors.

pub enum Result<T, E> {

Ok(T),

Err(E),

}

Appendix C: Compiler

C1. Immutability:

The compiler guarantees that when you state immutable variables, the value really won’t change. This is done by getting compiler errors.

Note that mutating an instance in place is faster than copying and returning newly allocated instances.