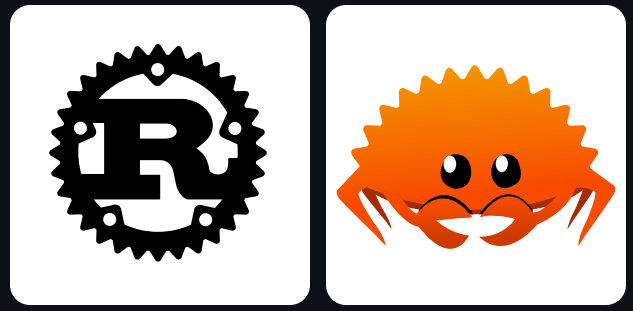
Introduction to the Rust programming Language



Following along The Rust Book from the official source

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For: **IFT-769** (Theoritical concepts CS)

📖 **Project overview -** Going through "The Rust Programming Language"

The Rust Programming Language by Steve Klabnik and Carol Nichols

Book overview:

- Official guide to the Rust programming language
- Covers the basics (syntax, types, functions) + toolchain
- Advanced and Rust-specific features:
  - Ownership, borrowing, lifetimes
  - Unique error handling
  - Concurrency

Klabnik, Steve, and Carol Nichols. The Rust Programming Language. 2nd ed., No Starch Press.

📚 **Theoretical concepts** - Key topics covered

1. Common Programming Concepts (*variables, types, control flow*)
2. Understanding Ownership (*memory management*)
3. Structs, Enums and Pattern Matching
4. Containers/Collections
5. Error Handling
6. Generics, Traits and Lifetimes
7. Functional and OO features
8. Smart pointers and Concurrency
9. Patterns and matching + Advanced features

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Rust Overview

- **Systems programming language** focused on **safety** and **performance**
- TODO

Currently known projects

TODO

Predicted use cases

TODO

Pros and Cons of Rust

PROS:

- **Memory safety**: No null pointers, dangling pointers, or buffer overflows
- **Error handling**: With the `Result` and `Option` types
- **Concurrency**: Safe and efficient with the ownership system
- **Performance**: Comparable to C/C++ with zero-cost abstractions
- **Ecosystem**: Growing with a strong community and package manager (**Cargo**)
- **Helpful compiler**: Provides detailed error messages and warnings

CONS:

- **Learning curve**: Ownership, borrowing, and lifetimes can be challenging
- **Tooling and prevalence**: Not as mature as other languages (C/C++, Python, etc.)
- **Syntax**: Can be verbose and complex compared to other languages

⚙️ Installation and setup

Installation:

1. Install Rust using `rustup` (Rust toolchain installer)

Included toolchain:

- `rustc`: Rust compiler
- `rustup`: Rust toolchain manager
- `rustfmt`: Rust code formatter
- `cargo`: Rust package manager and build tool

Package and library management

- **Crates** are Rust packages that can be shared and reused
- Managed with **Cargo**, the Rust package manager

 **Development environment** - Toolchain overview

Env setup and features:

- Easy install: `curl --proto '=https' --tlsv1.2 -sSf https://sh.rustup.rs | sh`
- Rustup for managing toolchains: `rustup update`
- Included formatter: `rustfmt --check src/main.rs` (dry-run mode)
- Cargo for building and managing projects: `cargo new project_name`
- Quality of life with `rust-analyzer`: LSP, build/debug IDE support etc.

Development environment - Cargo features

Useful Cargo commands when building a project:

- `cargo build` or `cargo run` to compile and run the project. Use `--release` flag for compilation with optimizations inside `target/release/`
- `cargo check`: Check the project for errors without building
- `cargo doc`: Generate documentation for the project
- `cargo clean`: Remove build artifacts
- `cargo update`: Update dependencies
- `cargo fmt`: Format the code according to the Rust style guidelines
- `cargo test`: Run tests in the project

🛠️ **Practical project #0 -** Guessing game

Great way to introduce to the development environment and basic concepts of Rust:

- Common programming concepts (types, funcs, control flow)
- Use of another crate (rand) inside the project
- I/O, String manipulation, error handling
- Compiler warnings and error messages
- `rust-analyzer` compiler FE for IDE support

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🚀 Demo Time!

Simple guessing game CLI app 🎲 (Basics and dev environment features)

🔎 **Demo reminders** - P#0 (Guessing game)

- `Result` type with `.expect()` for error handling
- `cargo doc --open` to generate and view documentation
- `cargo fmt` to format the code
- Type annotations and `let` for variable declaration

Variables and mutability

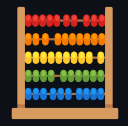
Variables are immutable by default

```
let x = 5;              // immutable variable
x = 10;                 //!ERROR!

let mut y = 10;         // mutable variable
y = 15;                 // Will compile (overwrite with same type)
let y = "hello";        // Will compile (shadowing)
```

Constants are always immutable within the scope

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



Statically typed + type inference

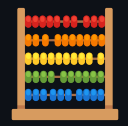
`rust-analyzer` provides type hints and suggestions

```
let secret_num = rand::thread_rng().gen_range(1..101); // Will infer i32 type
```

Explicit type annotations can or must be used

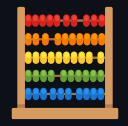
```
let mut num: String = String::new(); // Can be annotated or inferred
num = "42".to_string();

let guess = guess.trim().parse().expect("Please enter a number");  // Wont Compile
let guess: u32 = guess.trim().parse().expect("Please enter a number"); // Will compile
```



Data types - Scalars

Data type	Size	Specifity
int	8-128 bits	signed/unsigned
float	32/64 bits	simple/double precision
char	4 bytes	unicode
bool	1 byte	true/false



Data types - Compound

Data type	Size	Elements	Example	Access
tuple	fixed	mixed types	`(1, "hello", 3.14)`	`tuple.0`
array	fixed	same type	`[1, 2, 3, 4, 5]`	`array[0]`
vec	dynamic	same type	`vec![1, 2, 3, 4, 5]`	`vec[0]`

Access safety with runtime bounds checking. If using `array[10]` will panic at runtime instead of *undefined behavior like in C/C++*

Functions - `main`

Functions are defined with the `fn` keyword. All programs start with a `main` function

```
fn main() {
    println!("Hello, world!");

    say_hello_back();
}

fn say_hello_back() {
    println!("Hello back!");
}
```

Functions - Parameters and return

Function signatures and use:

- Parameters must have type annotations
- Return type must be specified with `->`
- Functions can return multiple values with tuples

```
fn main() {
    let num_sum = add(5, 10);
    println!("The sum is: {}", num_sum);
}

fn add(x: i32, y: i32) -> i32 {
    x + y
}
```

📜 Statements

- `let` is a statement, and `x + y` is an expression.
- Compared to C/C++, var assignment is an expression in Rust and **does not** return a value
- Statements must end with a semicolon `;`

```
let x = 5;          // statement
let y = z = 10;     // ERROR! z = 10 does not return a value
```

Expressions

- Expressions **evaluate** to a value (*func calls, operations, blocks*)
- No `;` at the end of expressions
- **Blocks** `{}` are expressions and can be used to create new scopes + return values

```
fn main() {
    let x = 5; // whole line is statement, 5 is expression
    let y = {
        let x = 3;
        x + 1
    }; // an expression
    println!("The value of y is: {}", y); // Prints 4!
}
```

🧰 Control Flow - Conditionals

if/else: (Only takes boolean expressions)

```rust
// Classic if/else if/else
let mut condition = false;
if number < 5 {
    println!("Too small!");
} else if number > 5 {
    println!("Too big!");
} else {
    println!("Just right!");
    condition = true;
}

// Assignement with if/else
let result = if condition { 5 } else { 6 };
```

Control Flow - Loops overview

3 types of loops in Rust: `loop`, `while` and `for`

- `loop`: Infinite loop until `break` or return
- `while`: Loop while condition is true
- `for`: Loop over an iterator

```
// Conditional loop
let mut counter = 0;
while counter < 10 {
    println!("counter = {counter}");
    counter += 1;
}
```

Control Flow - Loop labels

Loop labels can be used to distinguish nested loops (*break* and *continue*)

```
fn main() {
    let mut count = 0;
    'counting_up: loop { // Label the outer loop
        println!("count = {count}");
        let mut remaining = 10;

        loop {
            println!("remaining = {remaining}");
            if remaining == 9 {
                break;
            }
            if count == 2 {
                break 'counting_up;   // Break the outer loop
            }
            remaining -= 1;
        }
        count += 1;
    }
    println!("End count = {count}");
}
```

Control Flow - Collection with `for`

No need for manual indexing, `for` loops iterate over collections

```
let collection = [10, 20, 30, 40, 50];
for element in collection {
    println!("The value is: {element}");
};
```

Ownership - TODO

TODO

🛠️ **Practical project #1 -** Write an I/O CLI program

Halfway project for a `grep` clone CLI app covers:

1. Code organization (crates, modules)
2. Use of containers and strings
3. Error handling
4. Using traits and lifetimes
5. Testing and documentation

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🛠️ **Practical project #2 -** Building a Multithreaded Web Server

Final Project from the book includes :

1. Learn TCP/IP networking and HTTP
2. Listen to TCP connections on a socket
3. Parse HTTP requests
4. Generate HTTP responses
5. Handle multiple requests concurrently with a thread pool

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THEORY STUFF

TODO