Comprehensive Rust for Embedded System (60 Hours)

This curriculum provides a well-structured learning path for mastering Rust development, integrating specific topics with debugging, target-specific optimization, and code optimization techniques.

Learning Objectives:

- Gain a strong foundation in core Rust concepts
- Apply asynchronous programming with Tokio and Futures
- Work with Rust Foreign Function Interface (FFI) for C interoperability
- Develop socket programming applications in Rust
- Profile and optimize Rust code for performance
- Understand Rust's memory model and manage lifetimes effectively
- Build applications for embedded systems with Rust (no_std environment)
- Implement robust error handling mechanisms in Rust applications
- Leverage the Rust libc crate for platform-specific functionality

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Hours 0-8:

Hours 9-14:

Asynchronous Programming with Tokio and Futures

- **Hands-on:** Building a simple web server using Tokio
- Introduction to asynchronous programming in Rust
- Understanding Tokio, an asynchronous runtime for Rust
- Working with futures and async/await syntax
- Implementing asynchronous tasks and handling concurrency
- Error handling in asynchronous code
- Debugging asynchronous code with `--debug` flag

Hours 15-20: Rust Foreign Function Interface (FFI) with C

- **Hands-on:** Integrating Rust with a C library to perform image processing
- Introduction to FFI and its importance
- Interfacing Rust code with C libraries
- Using `extern` blocks and `unsafe` code
- Passing data between Rust and C functions
- Handling different types and memory management

- Debugging FFI code with `--debug` flag
- Optimizing FFI code with `--Z mir-opt-level`, `--Z fuel=<crate>=<value>`, and `--codegen-units`
- Target-specific optimization with `RUSTFLAGS="-C target-cpu=native"`

Hours 21-25: Socket Programming in Rust

- **Hands-on:** Building a chat application using Rust sockets
- Overview of networking in Rust
- Creating TCP and UDP sockets
- Implementing server-client communication
- Handling connections and streams
- Error handling and asynchronous networking
- Debugging socket code with `--debug` flag

Hours 26-41: Rust Benchmarking and Optimization for Target Hardware

- **Hands-on:**
- Rust code optimization
- -C target-cpu=native (assuming it's an Intel processor).
- Understanding Rust's performance characteristics
- Hands on Benchmark | perf | FlameGraph | valgrind
- Profiling Rust code and identifying bottlenecks
- Techniques for benchmarking and performance testing
- Optimizing Rust code for specific hardware targets
- Using compiler flags and optimization techniques

Hours 42-47: Rust Memory Model and Lifetimes

- **Hands-on:** Implementing a data structure with strict lifetime requirements
- Understanding Rust's ownership model
- Exploring references and borrowing in Rust
- Lifetimes and how they enforce memory safety
- Avoiding common pitfalls related to memory management
- Advanced memory management techniques
- Debugging memory-related issues with `--debug` flag
- Optimizing memory usage with `--Z mir-opt-level`, `--Z fuel=<crate>=<value>`, and `--codegen-units`
- Target-specific optimization with `RUSTFLAGS="-C target-cpu=native"`

Hours 48-54: Rust for Embedded Systems (no_std, Interrupts)

- **Hands-on:** Writing firmware for a microcontroller using Rust
- Introduction to embedded systems development with Rust
- Using the `no_std` environment and custom allocators
- Interfacing with hardware peripherals and sensors
- Handling interrupts and real-time constraints
- Building and deploying Rust code on embedded platforms
- Debugging embedded code with `--debug` flag
- Optimizing embedded code with `--Z mir-opt-level`, `--Z fuel=<crate>=<value>`, and `--codegen-units`
- Target-specific optimization with `RUSTFLAGS="-C target-cpu=native"`

Hours 55-60: Error Handling and Panic in Rust

- **Hands-on:** Writing a robust file parsing library with comprehensive error handling
- Understanding error handling mechanisms in Rust
- Using `Result` and `Option` for error propagation
- Handling panics and unwinding behavior
- Customizing panic behavior with `panic` macros
- Best practices for error