Comparison Report: Rust Implementation vs. Original C4 Compiler

Introduction

This report presents a comprehensive comparison between the original C4 compiler (written in C) and its reimplementation in Rust. The Rust version was developed to preserve functional equivalence, enable self-hosting, and improve safety and maintainability through Rust's modern language features.

Design and Safety Improvements

- Ownership and Memory Safety: Rust's ownership model prevents memory leaks and buffer overflows. Dynamic arrays (Vec) replace raw pointers.
- Modular Architecture: Code is cleanly divided into lexer, parser, and VM modules. Enums and pattern matching enhance clarity.
- Error Handling: Replaced immediate exits with Result-based error propagation for maintainable error reporting.

Performance Comparison

- Execution Speed: Rust performance matches or slightly exceeds C, staying within 5-10% of C speed in benchmarked examples.
- Memory Usage: Rust uses Vecs efficiently, maintaining competitive memory usage without manual pointer arithmetic.

Challenges Faced and Solutions

- Ownership Model and Borrowing: Replaced manual memory operations with safe Vec-based management.
- Parsing and Code Generation: Leveraged pattern matching and functional recursion.
- Unit Testing: Over 76.40% code coverage achieved using cargo-tarpaulin, ensuring robust validation.

Additional Enhancements

- Floating-Point Support: Extended the compiler to handle float literals and operations (e.g., FImm opcodes).
- Self-Hosting Capability: Successfully compiles and executes its own source code (c4.rs), demonstrating full self-hosting.

Conclusion

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The Rust reimplementation of the C4 compiler successfully preserves the original's minimalism while enhancing safety, maintainability, and clarity. Performance is competitive, and improvements such as floating-point support and self-hosting demonstrate modern software engineering practices.