UC DAVIS
COMPUTER SCIENCE

VRV: A Versatile RISC-V Simulator for Education

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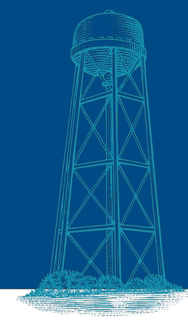


Motivation

- SPIM used to be a reference as a multi-platform educational (*MIPS32*) simulator
  - Featured in Hennessy and Patterson's seminal textbook.
- However, MIPS32 is no longer relevant, and RISC-V has become its de facto replacement.
- Need for RISC-V simulator with the same features as SPIM!
  - CLI client for headless environments (e.g., autograder) or power-users
  - GUI client for regular users
  - Multi-platform
  - Integrated debugger
  - Optional system-level programming
  - Optional I/O devices

Existing RISC-V educational simulators

- BRISC-V (https://ascslab.org/research/briscv/simulator/simulator.html)
  - Online simulator in Javascript
  - No CLI client (i.e., no headless autograder)
  - No system-level programming or I/O devices
- RARS (https://github.com/TheThirdOne/rars)
  - Cross-platform simulator in Java
  - Does meet all the requirements, but limited evolution to offer an web client

```
$ ./vrv f_to_c.s
Loaded: <built-in system file>
Loaded: f_to_c.s
100
Temperature in Fahrenheit is: 100
Temperature in Celsius is: 37.77777863
```

Our simulator: VRV

- Command line interface (**vrv**) and graphical user interface (**qvrv**)

- Multi-platform
  - Linux and Windows/WSL via AppImage applications
  - Mac OS via homebrew or universal package

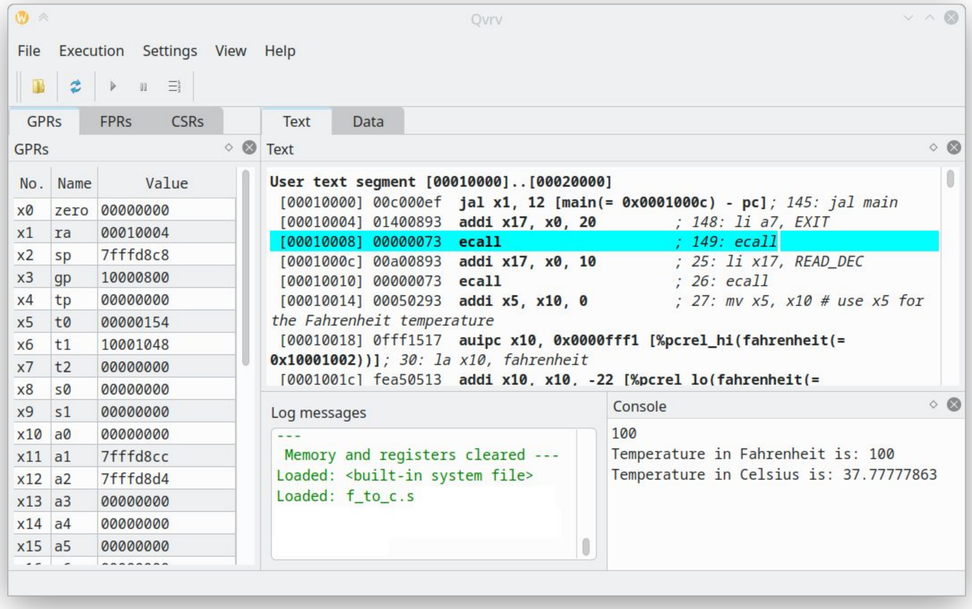
- Implements `RV32IMF_Zicsr` instruction set
  - 32-bit base integer instructions (*RV32I*)
  - Integer multiplication and division support (*M-extension*)
  - Single-precision floating-point support (*F-extension*)
  - Control and status registers support (*Zicsr-extension*)

- Supports Machine and User modes
  - User-level programs
  - System-level code (e.g., exception/interrupt handlers)

- Includes a simple, optional memory-mapped TTY device
  - Based on LupIO-TTY (https://gitlab.com/luplab/lupio/lupio-specs)

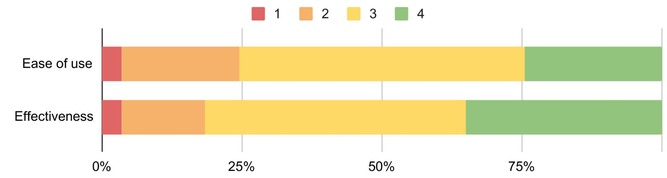
- Integrated assembler
  - Resolves symbol references
  - Expands pseudo-instructions

- Integrated debugger
  - Breakpoints, watchpoints, memory/register display



Classroom experience

- Lower-division computer organization class (ECS 50) during Fall 2023 term
- Basic user programs
  - Coin change calculation, temperature conversion
  - Sorting + binary search using functions
- Advanced system code
  - Trap handler emulating misaligned memory accesses
- Very positive students' feedback



Project

- Website: https://gitlab.com/luplab/vrv/vrv
- Open-source available under the GNU Affero GPL v3.0

- Email: jporquet@ucdavis.edu
- Lab: https://luplab.cs.ucdavis.edu/