InspireRV: Namecard-Sized RISC-V Computer for Foundational Digital Literacy and Computational Thinking

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Abstract: *Most students today use heavily on personal computers, tablets, and smartphones, yet few understand the foundational principles governing digital computation—how binary values represent instructions, how machine code corresponds to processor operations, or how high-level languages translate into sequences of zeros and ones. This disconnect limits digital literacy and limits innovation and breakthrough.*

This paper presents InspireRV, an innovative namecard-sized (55×85 mm) RISC-V–based edutainment computer designed specifically to teach foundational concepts of computation through direct manipulation of machine code, for students starting from around 12 years old. Unlike conventional coding tools, InspireRV allows students to physically enter binary instruction bits using an integrated 64-LED/64-button clickable display, visualize execution in real time, and explore RISC-V operations through games, animations, robotics, and small-scale deep-learning experimentation.

The device functions without a PC or tablet or internet, lowering access barriers for schools and workshops. This work describes the system's design, educational rationale, implementation of RISC-V instruction interpretation, extension modules (OLED disassembler instruction display, robotic base, deep-learning digit recognizer), and the pedagogical model supporting its deployment in secondary and tertiary education. InspireRV aims to ignite conceptual curiosity, strengthen digital literacy, and inspire future innovators to explore processor architecture and computational engineering.

Keywords: RISC-V, computational thinking, instruction set, processor, tangible computing.

1. Introduction

Digital technologies affect all aspects of modern life. Despite daily interaction with computers and smartphones, most users remain unaware of how software becomes 0 and 1, how binary instructions control processors, or how instruction sets operate at the lowest levels. This widening "computational literacy gap" limits the public's ability to critically understand the news of chips and software, digital systems, constrains the pipeline of students pursuing deep computing disciplines, and creates barriers to innovation in computer architecture.

Conventional computing education focuses primarily on high level programming languages or graphical interfaces, leaving machine code and processor design as niche topics restricted to advanced university courses. Yet emerging open architectures such as RISC V offer new opportunities for educational democratization: because the instruction set is open, modifiable, and free, it provides an authentic platform for students to understand real-world processor behavior.

To address this educational need, we introduce InspireRV platform (fig 1), which is based on a compact, namecard sized educational computer designed to teach the fundamentals of binary representation and RISC V machine instructions through hands on, playful experimentation. The device emphasizes physical interaction, tactile learning, and immediate visual and audio feedback, transforming abstract concepts into intuitive experiences. Students can toggle instruction bits, observe the effect on display patterns, movement, or sound, and connect these actions to processor operations.

This paper presents InspireRV's system architecture, educational purpose, hardware design, embedded interpreter, and extension capabilities, and positions it as a novel platform for computational literacy and STEM engagement.

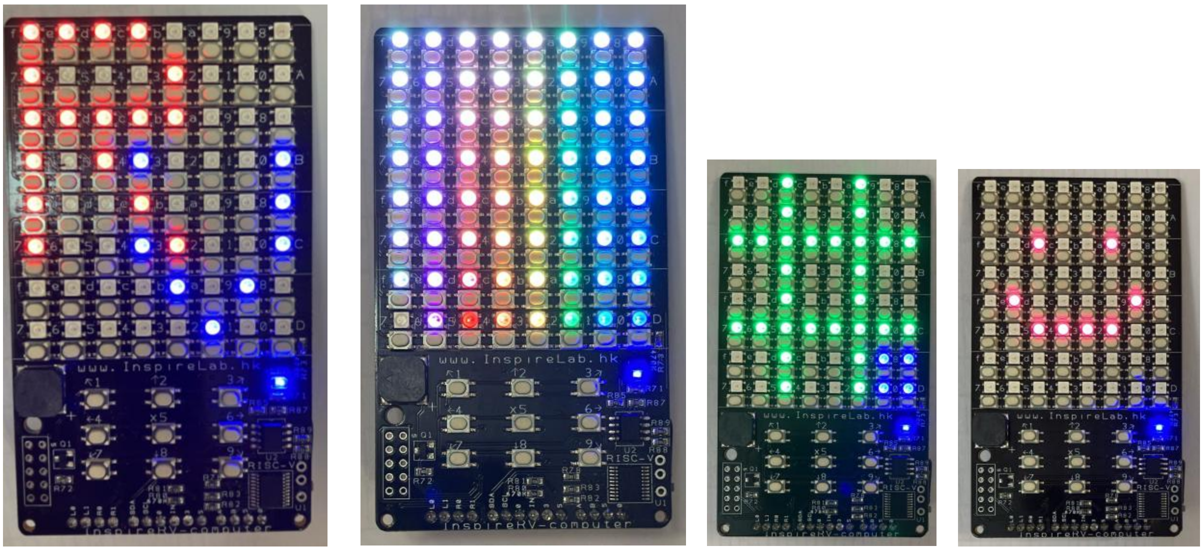


Fig 1. Namecard size computer with clickable color display

2. Background and Related Work

2.1 Digital Literacy and Foundational Computing Education

Prior research highlights the increasing need for foundational digital understanding among students. While tools like Scratch, Micro:bit, and Arduino help students learn programming at various levels, few systems provide exposure to machine-code–level operations. Foundational knowledge of binary and low-level computing is associated with improved computational thinking and deeper conceptual understanding.

2.2 RISC-V for low level software education

RISC-V, an open-source Instruction Set Architecture (ISA) originating from UC Berkeley, provides a lightweight, modular alternative to proprietary ISAs. Its public availability, simplified base instruction set, and widespread industry adoption make it a suitable platform for education. Educators have begun exploring RISC-V for teaching computer architecture, but typically through FPGA boards or software simulators—systems often too complex for beginners or too resource-heavy for scalable classroom adoption.

2.3 Limitations of Existing Educational Hardware

Existing teaching tools generally fall into two categories: (1) High-level coding environments—easy to use but abstract away machine-level details. (2) FPGA/prototyping boards—powerful but expensive, bulky and need computer interfacing, and requiring expert-level knowledge.

InspireRV bridges these extremes, offering a true processor-based machine-code learning tool that is small (namecard size), accessible, easy to use and inexpensive.

3. System Overview of InspireRV

3.1 Hardware Design

The InspireRV platform integrates the following core components:

- **RISC-V Core Processor**
  A low-cost RISC-V System on Chip (SoC) core executes instructions interpreted from user-entered binary sequences, with input and output pins for speaker, LEDs, buttons.

- **32 KB EEPROM Storage**
  Capable of storing over 200 colorful graphics, animations, text sequences, or custom binary software programs (machine code software).
- **Clickable Color Display**
  A color display with 8 x 8 pixels, each pixel have a clickable button for represent eight row of bytes (each byte with bit 0, bit 1,..,bit 7) or four session of 16 bit (bit 0, bit 1…bit a, bit f). This allow direct manipulation of bit for setting binary machine code instruction, and allow color graphics or pixel arts. The display of **64 full-color LEDs** paired with **64 tactile input buttons**, allowing binary instruction entry, color selection, pixel-level drawing, visual output of computation and execution flow.
- **Speaker**
  A small speaker for output different sound frequency and duration, enable one to use machine code to generate various ringtone and sound effects such as increasing frequency and decreasing frequency.
- **Built-in RISC-V Interpreter**
  Supports 16 bit instructions such as c.addi, enabling students to enter machine code directly, example of RISC instruction as follows, and let the students to know the design of processor instruction, with concept such as operator and operand, conditional and unconditional branch, arithmetic and logical operators, etc.

3.2 Expansion Modules - Disassembler Module (128×64)

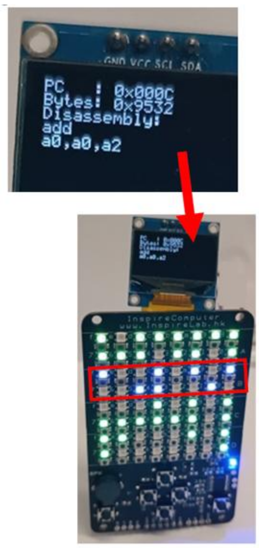
Provides textual output, enabling students to view decoded instructions (e.g., 0x9532 → add a0, a0, a2) and better connect binary to instruction (fig 2).

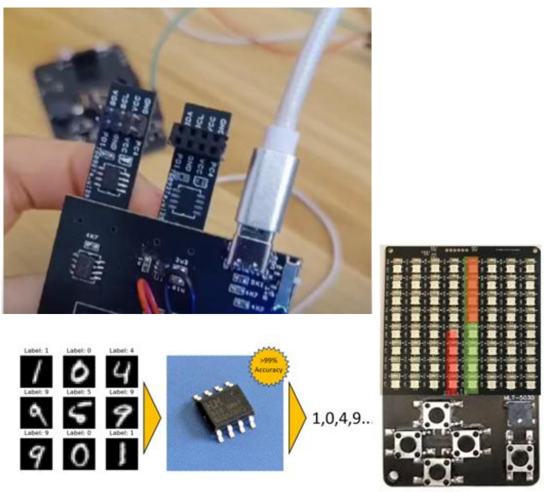
3.3 Expansion Modules - Deep Learning Module

Provide a digit recognition engine (0–9), let one to draw image on LED panel with buttons (in red color) and inspireRV will recognition the digit (in green color). For more advance education, there is open-source code for exploring fixed-point arithmetic, bit compression, and optimized AI inference.

3.4 Expansion Modules - Robotic Base Module

Allows InspireRV to drive motors (Fig 4) and perform stepwise motion control (such as move forward, left turn, move forward, right turn…). This allow the software to control movement and create "dancing" patterns





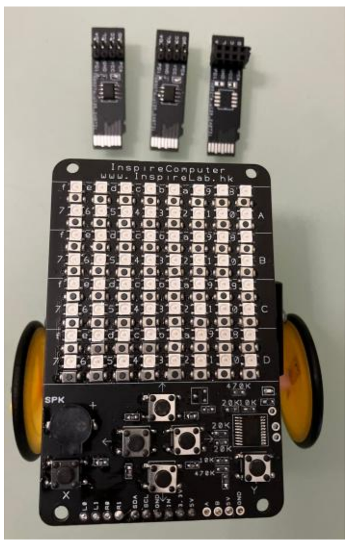


Fig 2. Disassembler Module Fig 3. Deep Learning Module Fig 4. Robotic Base Module

4. Pedagogical Value and Learning Model

The platform enables experiential learning of machine code through direct binary bit manipulation. Students typically encounter binary only in textbooks, and the platform brings binary to life by letting learners: (1) Enter and toggle real machine-code bits. (2) Visualize instruction effects immediately on screen patterns, animation, or sound. (3) Debug by modifying bits. (4) Observe changes as they experiment. This experiential approach supports: (1) constructivist learning, where knowledge is built through exploration. (2) embodied cognition, connecting tactile actions to conceptual understanding. (3) incremental abstraction, moving from physical bits → instruction → higher-level concepts. And the platform can democratize access to computer architecture as previously this is introduced in University courses. Because no personal computer or tablet is required, InspireRV facilitates truly mobile, hands-on technology workshop. The small size, low cost, and battery powered platform enable deployment such as educational workshops with hundreds of students, such as Hour of Code for RISC-V, STEM workshop, ArtsTech programs.

6. Evaluation and Educational Deployment Plan

Some pilot workshops with HK secondary school students was done, showed the platform can arose the student interest in learning the foundation of computer, and more flexible in venue such as classroom without personal computer and WiFi. In future we will organize and evaluate the effectiveness through events such as secondary school coding camp, University introductory digital-design courses and public STEM festivals. Evaluation metrics will include student engagement, concept comprehension (pre/post tests), interest in pursuing deeper computer engineering studies

7. Conclusion

InspireRV introduces a new class of educational technology: a namecard-sized machine-code learning computer that blends RISC-V open architecture with tactile, visual, and portable device. By lowering the barrier to understanding binary computation, the platform aims to cultivate a new generation of digital-literate students and inspire future innovators in processor architecture and embedded systems. Through its interactive LED/button interface, optional OLED disassembler, robotics capabilities, and embedded deep-learning engine, InspireRV provides a rich ecosystem for exploring computation from first principles. This work presents InspireRV as a scalable, accessible, and powerful tool for enhancing foundational computing education across secondary school and tertiary school levels.

References

Armoni, M. (2013). On Teaching Abstraction in Computer Science to Novices. Journal of Computers in Mathematics and Science Teaching, 32(3), 265–284. https://www.learntechlib.org/p/41271/

Hansen, A., Hansen, E., Dwyer, H., Harlow, D., & Franklin, D. (2016). Differentiating for Diversity: Using Universal Design for Learning in Elementary Computer Science Education. Proceedings of the 47th ACM Technical Symposium on Computing Science Education, pp.376–381.

Repenning, A., Webb, D. C., Koh, K. H., Nickerson, H., Miller, S. B., Brand, C., Horses, I. H. M., Basawapatna, A., Gluck, F., Grover, R., Gutierrez, K., & Repenning, N. (2015). Scalable Game Design: A Strategy to Bring Systemic Computer Science Education to Schools through Game Design and Simulation Creation. ACM Transactions on Computing Education, 15(2), 1–31. https://doi.org/10.1145/270051