IMPLEMENTING HANDS-ON ARMV8 INSTRUCTIONAL ACTIVITIES IN COMPUTER ARCHITECTURE EDUCATION: A CASE STUDY

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***Abstract**. In today's rapidly evolving technological landscape, computer architecture education plays a pivotal role in shaping the next generation of engineers and computer scientists. As ARM-based systems gain prominence across various domains, it becomes imperative to equip students with practical know ledge of ARMv8 architecture. In this study, we explore the integration of hands-on ARMv8 learning experiences using the Orange Pi 5 Plus single-board computer and virtual Linux environments. Our findings highlight the effectiveness of this approach in enhancing students' understanding of low-level programming and system design.*
***Keywords**: ARM, ARMv8, Orange Pi 5 Plus, Debugging with GDB, QEMU.*

The field of computer architecture encompasses the design and organization of computer systems, including processors, memory hierarchies, and input/output interfaces. As educators, our responsibility lies in preparing students to tackle real-world challenges by bridging theory with practice. ARM (Advanced RISC Machines) architecture, particularly ARMv8, has become ubiquitous in embedded systems, mobile devices, and cloud servers. Therefore, integrating practical ARMv8 experiences into computer architecture education is crucial.

Why focus on ARMv8? Here are some compelling reasons:

Widespread Adoption: ARM-based processors power billions of devices worldwide. Understanding ARMv8 is essential for future engineers.

Industry Demand: Employers seek graduates with hands-on experience in ARM architecture.

Educational Gap: While theoretical knowledge is essential, practical exposure is equally vital.

ARMv8 Education

Previous studies have emphasized the importance of teaching ARMv8 architecture in academic settings. However, most existing approaches rely heavily on theoretical lectures and simulations. Few studies delve into practical, hands-on experiences. Our research aims to address this gap by integrating tangible ARMv8 exercises.

Virtual Environments

Virtualization technologies offer a flexible and cost-effective way to simulate real-world scenarios. Virtual Linux environments allow students to experiment with ARMv8 assembly language programming, system calls, and memory management. By providing a safe sandbox for exploration, virtual environments bridge the gap between theory and practice.

Case Study Design

Our case study involved undergraduate computer science students enrolled in an advanced computer architecture course. Participants ranged from novices to those with prior programming experience. We selected the Orange Pi 5 Plus single-board computer due to its affordability, availability, and compatibility with ARMv8.

Experimental Setup

Hardware: The Orange Pi 5 Plus features an ARMv8 8-core 64-bit processor, 4 x Cortex-A76 and 4 x Cortex-A55 with independent NEON coprocessor. Cortex-A76 up to 2.4GHz, Cortex-A55 up to 1.8GHz (Figure 1). Thus, making it an ideal platform for ARMv8 experimentation.

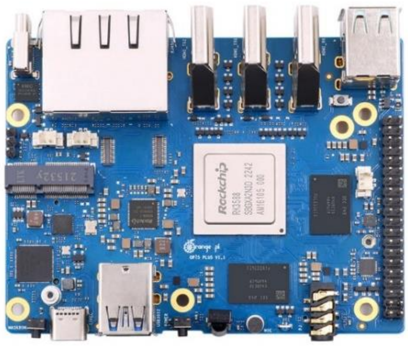

Figure 1 Orange Pi 5 Plus Hardware View

Virtual Linux Environments: We deployed virtual machines using QEMU (Quick Emulator) and Ubuntu-based ARMv8 images. Students accessed these environments remotely.

Learning Activities

Participants engaged in the following activities:

ARMv8 Assembly Programming: Students wrote and executed ARMv8 assembly programs, gaining insights into instruction sets, registers, and addressing modes.

Debugging with GDB: Debugging skills are critical. Participants learned to use the GNU Debugger (GDB) to identify and fix issues.

System Calls and Memory Management: Exploring system calls and memory allocation mechanisms deepened their understanding of operating system interactions.

Translating from high level language to assembly language. Students learnt how high-level languages like C language are translated into machine language.

Results

Our study has revealed several positive outcomes. Participants reported a significant increase in their confidence when working with ARM-based systems. This confidence was further bolstered by hands-on experiences that solidified their understanding of theoretical concepts. Moreover, students were able to transfer their knowledge of ARMv8 to other courses and personal projects, demonstrating the practical applicability of the skills they had acquired.

The pedagogical implications of our findings are profound. We found that practical exercises enhance both retention and comprehension, promoting active learning. Graduates equipped with ARMv8 skills are better prepared for industry roles, indicating the importance of these skills for career readiness. Furthermore, the use of virtual environments facilitates remote learning and collaboration, expanding the possibilities for distance education.

However, our study also identified some challenges. Resource constraints, particularly the availability of physical boards like the Orange Pi 5 Plus, may limit the scalability of our approach. Additionally, integrating practical sessions within a semester requires careful planning to overcome time constraints. Despite these challenges, the benefits of our approach are clear, and we believe it holds great promise for the future of education in this field.

Conclusion

By integrating practical ARMv8 learning experiences, educators empower students to bridge the gap between theory and practice. The Orange Pi 5 Plus and virtual Linux environments offer an effective, scalable approach. As ARM continues to shape the computing landscape, our efforts in enhancing ARMv8 education are pivotal.

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