

RESEARCH ARTICLE

OPEN ACCESS

Portable Raspberry Pi Based Smart Projector

Ranjeet Kumar¹, D Vijendar², T Sai Manoj³, K Ramana Reddy⁴,

¹ Department of Electronics & Communication Engineering, CMR Technical Campus, Hyderabad, India

² Department of Electronics & Communication Engineering, CMR Technical Campus, Hyderabad, India

³ Department of Electronics & Communication Engineering, CMR Technical Campus, Hyderabad, India

⁴ Department of Electronics & Communication Engineering, CMR Technical Campus, Hyderabad, India

*Corresponding author email: 247r1a0446@cmrtc.ac.in

Abstract — Conventional educational projectors generally depend on external computers, wired power sources, and additional presentation software, which limits portability and increases setup complexity in laboratories and resource-constrained teaching environments. This work presents a portable smart projector based on the Raspberry Pi 3B+ single-board computer, designed to provide standalone educational multimedia projection without continuous dependence on an external computer. The proposed system integrates local storage, a mini light-emitting diode projection module, rechargeable battery power, a Battery Management System (BMS), wireless connectivity, and a lightweight software environment for handling presentations, documents, images, and videos. Raspberry Pi operating system, Python-based control software, Video LAN Client multimedia playback, LibreOffice, and a graphical user interface were used for system implementation and testing. The prototype was evaluated through practical classroom and laboratory sessions using battery performance, thermal behavior, rendering efficiency, and playback frame rate as performance indicators. The system achieved a rendering efficiency of 0.939 and a playback rate of 23.44 frames per second, with a reported thermal dissipation value of 45.22°C. During operation, processor temperature remained approximately within 55–60°C, while battery voltage decreased from approximately 12.6 V to 10.5 V before battery management cutoff. The system also demonstrated more than two hours of operating runtime. The results demonstrate that the proposed projector can provide a compact, battery-powered, and practical alternative for portable digital education, engineering laboratories, workshops, and field-based teaching.

Keywords — Battery Management System; embedded system; educational technology; portable projector; Raspberry Pi; multimedia rendering.

I. INTRODUCTION

Conventional projection systems used in classrooms and engineering laboratories commonly depend on an external computer, wired power, and separate software for presenting digital learning material. Such dependencies increase setup time, cable complexity, and the need for fixed infrastructure, making conventional systems less suitable for mobile teaching, temporary classrooms, field demonstrations, and resource-constrained educational environments. Recent research has explored low-cost Raspberry Pi-based educational platforms, portable projectable computing systems, and improved projector connectivity. A low-cost classroom system based on Raspberry Pi demonstrated direct playback of videos and PowerPoint presentations, showing the feasibility of embedded computing for educational use [1]. A portable projectable mini-PC further integrated Raspberry Pi hardware with a compact projection unit and alternative interaction methods to

reduce dependence on conventional presentation equipment [2]. Raspberry Pi has also been applied to low-cost remote laboratory systems, demonstrating its suitability as an educational computing platform with local processing and graphical user interaction [3]. More recently, a low-cost Raspberry Pi architecture was proposed to improve projector management and connectivity by addressing compatibility and configuration problems between computing devices and projectors [4]. At the optical level, adaptive micro-projection research has focused on miniaturization, portability, and improved projection adaptability through advanced lens structures [5]. Although these studies establish the feasibility of low-cost embedded education and portable projection, the reviewed approaches generally address either educational computing, projector connectivity, remote experimentation, or optical miniaturization as separate objectives. A practical gap therefore remains in combining standalone

educational multimedia processing, battery-powered operation, integrated power management, simple user interaction, and thermal-performance evaluation within one compact projector intended for real-world academic use.

This paper addresses that gap through the development of a **Portable Raspberry Pi Based Smart Projector** centered on the Raspberry Pi 3B+. The proposed system integrates an optical projection module, rechargeable battery supply, Battery Management System, local storage, wireless connectivity, and a lightweight software environment for directly handling educational presentations, documents, images, and videos without an external computer. The project report describes the system as a standalone hardware-software architecture and evaluates it using battery, thermal, and multimedia-rendering parameters under practical laboratory conditions. The main contributions of this work are:

- A compact standalone projector architecture that combines Raspberry Pi-based multimedia processing, optical projection, rechargeable power, and Battery Management System integration.
- A lightweight software workflow using Raspberry Pi operating system, Python, Video LAN Client multimedia playback, LibreOffice, and a graphical user interface for local educational-content management.
- An experimental evaluation using practical educational sessions and quantitative performance metrics. The proposed system achieved a playback rate of **23.44 frames per second**, rendering efficiency of **0.939**, and a thermal dissipation value of **45.22 °C**. Compared with the tethered setup, these values correspond to approximately **11.8% higher playback rate**, **4.9% higher rendering efficiency**, and **37.3% lower thermal dissipation value**, respectively. The reported system was also operated for more than two hours, while processor temperature remained approximately within **55–60 °C** during continuous operation.

The remainder of the paper is organised as follows. Section II reviews related work. Section III describes the proposed methodology. Section IV presents experimental results. Section V concludes.

References corresponding to [1]–[5]

- [1] P. Srividya Devi, U. Vijaya Lakshmi, M. Rekha, and P. Sirisha, "Implementation of Low Cost Classroom Education Using the Smart Pi Zero," *Turkish Journal of Computer and Mathematics Education*, vol. 12, no. 10, pp. 6073–6077, 2021, doi: 10.17762/turcomat.v12i10.5432.
- [2] V. Shangamesh M. A., K. V. Anusuya, and V. Adithya, "Portable and Projectable Mini PC," *Proceedings of the First International Conference on Combinatorial and Optimization (ICCAP 2021)*, 2021, doi: 10.4108/eai.7-12-2021.2314725.
- [3] R. Zárate-Moedano, S. L. Canchola-Magdaleno, and A. A. Arrington-Báez, "Remote Laboratory, Based on Raspberry Pi, to Facilitate Scientific Experimentation for Secondary School Students," *International Journal of Online and Biomedical Engineering*, vol. 17, no. 14, pp. 154–163, 2021, doi: 10.3991/ijoe.v17i14.25525.
- [4] F. F. Paulo, P. F. Oliveira, and P. Matos, "A Low-Cost Solution to Improve Video Projector Management and Connectivity Using Virtualization," in *Proceedings of the 5th International Electronic Conference on Applied Sciences*, 2024.
- [5] C. Liu, Y. Zheng, F. Chu, Y.-W. Zheng, and Q.-H. Wang, "Adaptive Micro-Projection System Based on Liquid Lens," *Optics and Laser Technology*, vol. 167, Art. no. 109734, 2023, doi: 10.1016/j.optlastec.2023.109734.

II. RELATED WORK

Recent research on compact educational and projection systems can be broadly grouped into three themes: **Raspberry Pi-based educational platforms**, **portable projector and computing integration**, and **miniaturized/adaptive optical projection systems**. These themes establish the technological foundation for the proposed Portable Raspberry Pi Based Smart Projector while also revealing the gap between an

embedded educational computer and a completely standalone, battery-powered projection platform.

A. Raspberry Pi-Based Educational Platforms

Low-cost single-board computers have increasingly been investigated as alternatives to conventional computer-based educational infrastructure. Srividya Devi *et al.* presented a Raspberry Pi Zero-based classroom education system capable of playing videos and PowerPoint presentations, demonstrating the feasibility of using a compact Raspberry Pi platform for low-cost educational multimedia applications [1]. Zárate-Moedano *et al.* developed a Raspberry Pi-based remote laboratory for secondary-school physics education, where sensors and a graphical interface were used to provide remote access to scientific experiments [3]. The work demonstrated the affordability and educational usefulness of Raspberry Pi combined with free software and interactive interfaces, but its primary objective was remote experimentation rather than local multimedia projection.

These studies establish that Raspberry Pi platforms can provide computing, interaction, and educational functionality at relatively low hardware complexity. However, they do not fully address the combined requirements of an independent projector, integrated battery operation, optical output, thermal control, and multimedia playback in a single portable unit.

B. Portable Computing and Projector Integration

A second research direction focuses on reducing the dependence on conventional laptops and improving projector connectivity. Shangamesh *et al.* proposed a **Portable and Projectable Mini PC** using Raspberry Pi hardware, a projector module, voice control, and hand-gesture interaction through an ESP32 interface [2]. The system demonstrates how computing and projection functions can be integrated into a portable platform while providing alternative user-interaction mechanisms.

Paulo *et al.* subsequently proposed a low-cost architecture for improving the management and connectivity of existing video projectors using a Raspberry Pi and virtualized applications [4]. Their approach specifically addresses compatibility problems involving connectors, transmission protocols, frequency, and resolution, thereby improving the usability of older projector hardware.

Although these approaches reduce dependence on conventional desktop infrastructure, their objectives differ from those of the present work. The portable mini-PC approach emphasizes multimodal interaction, while the virtualization-based approach primarily improves projector management and connectivity. Neither is centred on a battery-powered projector designed to independently process and display educational media while simultaneously evaluating power and thermal performance.

C. Miniaturized and Adaptive Projection Systems

The third theme concerns the optical and mechanical miniaturization of projection hardware. Liu *et al.* proposed an adaptive micro-projection system based on liquid-lens technology, integrating a sequential three-color light source, liquid-crystal-on-silicon display, projection optics, display-driver electronics, and liquid-lens control. Their prototype achieved continuous adaptation over a working distance of approximately 150–310 mm and demonstrated 60 Hz colour-video display [5].

This research demonstrates the potential of advanced optical engineering to improve portability, adaptability, and projection performance. However, its emphasis is on the optical subsystem and adaptive zoom rather than on creating a low-cost educational appliance with an embedded computing platform, local educational-content management, rechargeable power, and integrated system-level performance monitoring.

D. Research Gap and Positioning of the Proposed Work

The closest prior approaches each address an important part of the problem but leave a system-level gap. Compared with the Raspberry Pi remote laboratory of Zárate-Moedano *et al.* [3], the proposed work is not designed for remote experimentation; instead, it uses the Raspberry Pi 3B+ as a local multimedia processor and projection controller. Compared with the virtualization-based projector architecture of Paulo *et al.* [4], the proposed system is not intended merely to improve connectivity with an existing projector; it integrates computing, projection, rechargeable power, and battery management into a portable unit. Compared with the adaptive micro-projection system of Liu *et al.* [5], the proposed work does not attempt to introduce advanced

liquid-lens optical zoom; its contribution lies in practical system integration for educational applications, including standalone media playback, simplified user interaction, battery operation, and thermal-performance evaluation.

Thus, the principal contribution of this work is **not a new projection principle**, but a practical **hardware-software system architecture that integrates embedded multimedia processing, portable power, projection, and performance management into a standalone educational projector**. This distinction positions the proposed system between low-cost educational computing and advanced portable projection research while targeting a practical use case for laboratories, classrooms, workshops, and resource-constrained teaching environments.

References used in this section

- [1] P. Srividya Devi *et al.*, “Implementation of Low Cost Classroom Education Using the Smart Pi Zero,” *Turkish Journal of Computer and Mathematics Education*, vol. 12, no. 10, pp. 6073–6077, 2021.
- [2] V. Shangamesh M. A., K. V. Anusuya, and V. Adithya, “Portable and Projectable Mini PC,” *Proceedings of the First International Conference on Combinatorial and Optimization*, 2021.
- [3] R. Zárate-Moedano, S. L. Canchola-Magdaleno, and A. A. Arrington-Báez, “Remote Laboratory, Based on Raspberry Pi, to Facilitate Scientific Experimentation for Secondary School Students,” *International Journal of Online and Biomedical Engineering*, vol. 17, no. 14, pp. 154–163, 2021.
- [4] F. F. Paulo, P. F. Oliveira, and P. Matos, “A Low-Cost Solution to Improve Video Projector Management and Connectivity Using Virtualization,” *Proceedings of the 5th International Electronic Conference on Applied Sciences*, 2024.
- [5] C. Liu, Y. Zheng, F. Chu, Y.-W. Zheng, and Q.-H. Wang, “Adaptive Micro-Projection System Based on Liquid Lens,” *Optics and Laser Technology*, vol. 167, Art. 109734, 2023.

III. METHODOLOGY

The proposed system integrates a Raspberry Pi 3B+, LED optical engine, rechargeable battery, Battery

Management System (BMS), local storage, and software modules for standalone multimedia projection. The Raspberry Pi performs file processing, multimedia decoding, rendering, and system control, while the BMS regulates power delivery and the optical engine produces the projected output.

A. System Architecture

The input consists of PowerPoint files, PDF documents, images, and MP4 videos received through USB or local storage. The selected file is validated and loaded into the Raspberry Pi environment. System initialization allocates the required memory and processing resources before multimedia decoding.

The Raspberry Pi 3B+ executes the software stack consisting of Raspberry Pi OS, Python, VLC Media Player, LibreOffice, Tkinter, RPi. GPIO, and python-VLC. Decoded media is buffered and rendered before being transferred through HDMI to the projector driver. The BMS manages power distribution to the computing and optical sections, while thermal management maintains stable operation during continuous playback.

The complete processing sequence is:

Input Media → File Validation → Initialization → Decoding → Rendering → Power/Thermal Management → HDMI Output → Projection

The estimated battery runtime is calculated as:

$$BR = C_b / I_{avg} \quad (1)$$

where **BR** is battery runtime in hours, **C_b** is battery capacity in mAh, and **I_{avg}** is average current consumption in mA.

The processor temperature rise is represented by:

$$\Delta T = T_{CPU} - T_{amb} \quad (2)$$

where **T_{CPU}** is processor temperature and **T_{amb}** is ambient temperature.

B. Dataset and Pre-processing

This study does **not use a machine-learning dataset**; therefore, training, validation, and testing splits are not applicable. The evaluation uses application-level educational media consisting of presentations, PDF documents, images, and MP4 videos. These files are loaded from USB or local storage and processed directly on the Raspberry Pi.

Pre-processing consists of:

1. File-format validation.
2. System and display initialization.
3. Memory and processing-resource allocation.
4. Multimedia decoding.
5. Frame buffering and resolution scaling.
6. Audio-video synchronization.
7. HDMI output generation.

No publicly available benchmark dataset or dataset DOI is used in this work.

C. Experimental Setup

The prototype uses a **Raspberry Pi 3B+**, Mini LED projector module, rechargeable battery system, BMS, storage, wireless connectivity, and optical projection hardware. The software environment includes **Raspberry Pi OS, Python, Thonny, VLC Media Player, LibreOffice, Tkinter, RPi. GPIO, and python-VLC.**

Testing was performed using educational multimedia under different laboratory conditions, including varying projection distances, low-to-moderate ambient lighting, and extended playback periods. The system was evaluated using:

- **Battery Runtime (BR)**
- **Thermal Dissipation Rate (TDR)**
- **Rendering Efficiency (RE)**
- **Playback Frame Rate (FPS)**

The prototype was compared with tethered projection, micro-projector, and mobile-casting approaches. The proposed system achieved **23.44 FPS, 0.939 rendering efficiency, and 45.22 °C TDR.** During operation, the processor temperature remained approximately within **55–60 °C**, while battery voltage decreased from approximately **12.6 V to 10.5 V** before BMS cutoff.

Since this is an embedded-system implementation rather than a machine-learning model, parameters such as epochs, batch size, learning rate, and optimizer are not applicable. The documented experiment also does not specify exact software version numbers or a fixed

number of repeated runs; these should be added only if available from the actual prototype records.

IV. RESULTS AND DISCUSSION

The prototype was evaluated during practical laboratory operation using educational presentations and videos under different projection distances, ambient-light conditions, and continuous playback durations. The quantitative comparison used three baselines: tethered setup, micro-projector, and mobile casting. The measured parameters were Thermal Dissipation Rate (TDR), Rendering Efficiency (RE), and playback frame rate.

Table I. Quantitative comparison of the evaluated projection methods

Method	TDR (°C) ↓	RE ↑	Playback FPS ↑
Tethered Setup	72.10	0.895	20.97
Micro- Projector	45.10	0.867	22.36
Mobile Casting	88.70	0.812	20.10
PI Projector (Proposed)	45.22	0.939	23.44

↓ *lower is better*; ↑ *higher is better*.
The values are taken directly from the reported experimental comparison in the project report.

The proposed projector provides the **highest rendering efficiency and playback rate** among all evaluated methods. Relative to the tethered setup, RE increases from 0.895 to 0.939, corresponding to approximately **4.92% improvement**, while playback rate increases from 20.97 to 23.44 FPS, an improvement of approximately **11.78%**. The reported TDR decreases from 72.10 °C to 45.22 °C, representing approximately **37.28% lower thermal value**. These results indicate that integrating local multimedia processing with the power and thermal-management architecture improves rendering stability while reducing the thermal burden observed in the tethered comparison.

Compared with the micro-projector, the proposed method achieves approximately **8.30% higher RE** and

4.83% higher playback rate. However, its TDR is **0.12 °C higher** than the micro-projector (45.22 °C versus 45.10 °C), corresponding to a difference of approximately **0.27%**. Thus, the proposed architecture does not provide the lowest thermal value among all methods, but the difference is very small while its multimedia-rendering performance is substantially better.

The largest improvement occurs against mobile casting. The proposed system provides approximately **15.64% higher RE, 16.62% higher playback rate, and 49.02% lower TDR** than the mobile-casting baseline. This suggests that local processing avoids some of the performance variation associated with externally cast multimedia content.

Qualitative Analysis

The prototype produced clear educational text, circuit diagrams, source-code syntax, and hardware illustrations during laboratory testing. Video playback remained visually stable, while the standalone interface reduced cable dependency and simplified file selection. The implemented workflow allows the operator to select a file through the graphical interface and start projection without connecting a separate laptop.

The battery profile shows a gradual voltage reduction from approximately **12.6 V at the beginning of operation to about 10.5 V near the Battery Management System cutoff.** Processor temperature initially rises and then remains approximately within **55–60 °C**, indicating comparatively stable thermal behaviour during sustained multimedia playback.

Limitations and Failure Cases

The experimental results also identify practical limitations. The proposed projector does not achieve the lowest TDR because its measured value is marginally higher than that of the micro-projector baseline. Projection quality is also influenced by ambient illumination and projection distance; the reported evaluation therefore focused on practical laboratory conditions rather than complete dark-room or outdoor characterization. The Raspberry Pi 3B+ is additionally subject to processing and thermal constraints when higher-complexity multimedia content is used. These limitations indicate that optical brightness, cooling, and processing capability remain important areas for further improvement.

Ablation Analysis

A formal ablation study was **not performed or reported in the project documentation**, so numerical ablation results should not be claimed in the IJET paper. However, the architecture contains three major design elements whose intended roles can be identified: the Raspberry Pi 3B+ provides local multimedia processing, the Battery Management System provides regulated battery operation and protection, and the optical engine produces the projected image. The project methodology specifically attributes stable power delivery and reduced overheating to the integrated power-management arrangement.

The available results therefore support the conclusion that the complete integrated architecture performs better than the evaluated baselines in rendering efficiency and playback stability, while maintaining a thermal profile close to the best-performing baseline. A controlled component-removal ablation, with identical workloads and repeated measurements, would be required to quantitatively isolate the contribution of each subsystem.

Experimental Reporting Note

The project report gives **single reported values for the comparison table** and does not provide mean $\pm$ standard deviation or the exact number of repeated measurements for each metric. Therefore, mean $\pm$ standard deviation values have **not been invented**. The report does state that the projector was tested across **50 real-world classroom sessions**, which supports the practical nature of the evaluation, but the underlying per-run measurements are not provided.

V. CONCLUSION AND FUTURE WORK

The proposed Portable Raspberry Pi Based Smart Projector integrates embedded multimedia processing, battery-powered operation, power management, and optical projection into a single standalone educational platform. The strongest experimental result was a **23.44 frames-per-second playback rate with 0.939 rendering efficiency**, while maintaining a processor temperature of approximately **55–60 °C** during operation, demonstrating stable multimedia performance for portable educational use.

Future work will focus on (1) replacing the Raspberry Pi 3B+ with a more capable and energy-efficient embedded processor to support higher-resolution and more demanding multimedia, (2) improving the optical subsystem, battery capacity, and thermal design for longer field operation in rural classrooms, workshops, and outdoor teaching environments, and (3) conducting larger controlled experiments with repeated measurements, standardized projection conditions, and additional parameters such as brightness, resolution, power consumption, and long-term reliability. The project documentation identifies rural education, mobile laboratories, workshops, and field applications as relevant deployment areas.

VI. DECLARATIONS

A. Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

B. Conflict of Interest

The authors declare no conflict of interest.

C. Data Availability

The data that support the findings of this study are available from the corresponding author on reasonable request.

D. Ethics Statement

This study did not involve human or animal subjects.

E. Author Contributions

The project report identifies **Ranjeet Kumar Beldar, D. Vijendar, T. Sai Manoj, and K. Ramana Reddy** as the project authors, under the guidance of **Dr. Bandi Doss**.

Roles of all authors:

Conceptualization, R.K.B., D.V., T.S.M., and K.R.R.; Methodology, R.K.B. and D.V.; Software, R.K.B.; Hardware implementation, T.S.M. and K.R.R.; Validation, D.V. and T.S.M.; Investigation, all authors; Writing — original draft, R.K.B. and D.V.; Writing — review and editing, all authors; Supervision, B.D.

VII. ACKNOWLEDGMENTS

The authors sincerely acknowledge **CMR Technical Campus, Department of Electronics and Communication Engineering**, for providing the laboratory infrastructure and resources required to develop and evaluate the proposed system. The authors also thank **Dr. Bandi Doss, Professor**, for his guidance and technical support throughout the project.

VIII. REFERENCES

- [1] P. Srividya Devi, U. Vijaya Lakshmi, M. Rekha, and P. Sirisha, "Implementation of low cost classroom education using the Smart Pi Zero," *Turkish Journal of Computer and Mathematics Education*, vol. 12, no. 10, pp. 6073–6077, Apr. 2021, doi: 10.17762/turcomat.v12i10.5432.
- [2] V. Shangamesh M. A., K. V. Anusuya, and V. Adithya, "Portable and projectable mini PC," in *Proc. First International Conference on Combinatorial and Optimization (ICCAP)*, Chennai, India, Dec. 2021, doi: 10.4108/eai.7-12-2021.2314725.
- [3] R. Zárate-Moedano, S. L. Canchola-Magdaleno, and A. A. Arrington-Báez, "Remote laboratory, based on Raspberry Pi, to facilitate scientific experimentation for secondary school students," *International Journal of Online and Biomedical Engineering*, vol. 17, no. 14, pp. 154–163, Dec. 2021, doi: 10.3991/ijoe.v17i14.25525.
- [4] F. F. Paulo, P. F. Oliveira, and P. Matos, "A low-cost solution to improve video projector management and connectivity using virtualization," in *Proc. 5th International Electronic Conference on Applied Sciences*, Dec. 2024.
- [5] C. Liu, Y. Zheng, F. Chu, Y.-W. Zheng, and Q.-H. Wang, "Adaptive micro-projection system based on liquid lens," *Optics and Laser Technology*, vol. 167, Art. no. 109734, Dec. 2023, doi: 10.1016/j.optlastec.2023.109734.

© Year The Author(s). Published by the International Journal of Engineering and Techniques (IJET). This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. License: <https://creativecommons.org/licenses/by/4.0/>