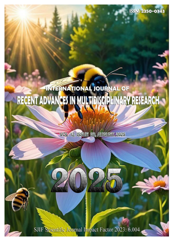
International Journal of Recent Advances in Multidisciplinary Research

ISSN : 2350-0743

Vol. 12, Issue 08, pp.11645-11649, August, 2025

https://doi.org/10.64485/ijramr.6073.08.2025



RESEARCH ARTICLE **CROSSREF** **OPEN ACCESS**

HANDHELD MULTISPECTRAL UV–IR IMAGING SYSTEM FOR REAL TIME DETECTION OF CHEATING SLIPS AND VISIBLE AND INVISIBLE INKS DURING ACADEMIC EXAMINATIONS

[1]Dr. Nellutla Sasikala, [2]Dr. Praveen Kumar Rao K. and [3]Mr. Prashanth Kumar D.

[1]Department of Electronics and Communication Engineering, Kamala Institute of Technology & Science, Karimnagar, India
[2]Department of Artificial Intelligence and Machine Learning, Kamala Institute of Technology & Science, Karimnagar, India
[3]Department of Computer Science and Engineering, Kamala Institute of Technology & Science, Karimnagar, India

ARTICLE INFO

Article History

Received 24th May, 2025
Received in revised form
27th June, 2025
Accepted 20th July, 2025
Published online 30th August, 2025

Keywords:

Multispectral Imaging, UV–IR Illumination, Real Time Cheating Detection, Embedded Systems, Raspberry Pi, Invisible Ink Recognition, Computer Vision, Examination Security, Educational Surveillance, Open CV.

Corresponding author:
Dr. Nellutla Sasikala

ABSTRACT

The increasing sophistication of cheating techniques in academic examinations—such as the use of invisible inks and microprinted notes—presents a challenge to conventional invigilation methods. This paper presents the design and implementation of a handheld, embedded multispectral scanner capable of detecting concealed ink markings in real time. The proposed system employs ultraviolet (UV), infrared (IR), and visible spectrum illumination sources, integrated with a Pi Camera and Raspberry Pi 4 processing unit. Spectral images are captured sequentially and analyzed using OpenCV based computer vision algorithms, including adaptive thresholding, contour detection, and edge based segmentation. The device provides immediate visual and auditory alerts upon detection and operates entirely offline. Experimental evaluations across various ink types and substrates demonstrated a detection accuracy of 96%, validating the system's reliability in practical examination settings. The proposed solution offers a cost effective, portable, and scalable tool for educational institutions seeking to enhance examination security through embedded vision technologies.

Citation: Dr. Nellutla Sasikala, Dr. Praveen Kumar Rao K. and Mr. Prashanth Kumar D. 2025. "Handheld multispectral uv–ir imaging system for real time detection of cheating slips and visible and invisible inks during academic examinations", International Journal of Recent Advances in Multidisciplinary Research, 11, (08), 11645-11649.

INTRODUCTION

The integrity of academic assessments is a cornerstone of educational credibility. As learning environments expand and student numbers increase, the risk of examination malpractice has also grown in complexity. While traditional forms of cheating have existed for decades, recent technological and material innovations have introduced more elusive techniques—such as micro printed notes, ultraviolet (UV) reactive invisible inks, and infrared (IR) absorbent markings applied to skin or clothing. These forms of cheating are often undetectable under standard lighting or without specialized equipment, posing a significant threat to secure examination practices. Conventional methods of invigilation, including CCTV monitoring, manual frisking, and metal detectors, provide limited effectiveness in identifying non metallic and visually hidden content. Moreover, these solutions tend to be invasive, resource intensive, or unsuitable for dynamic, large scale academic settings. The lack of real time, portable, and non intrusive solutions leaves educational institutions vulnerable to evolving threats to examination integrity. This study presents a novel solution in the form of a compact, handheld multispectral scanner specifically designed to detect ink based cheating aids in real time. Utilizing UV and IR illumination, combined with a visible spectrum baseline, the device captures multiple spectral frames which are processed using embedded computer vision algorithms. The system identifies spectral anomalies indicative of hidden inks and provides immediate feedback to examiners. Built using affordable components such as a Raspberry Pi and open source software libraries, the solution is portable, cost effective, and easy to operate.

The development and testing of this device align with broader goals in educational technology: safeguarding the fairness of assessments, enhancing invigilation efficiency, and introducing scalable innovations that maintain academic standards. The rest of this paper outlines the device architecture, image processing methodology, experimental evaluation, and implications for adoption within academic institutions.

LITERATURE REVIEW

Efforts to reduce examination malpractice have increasingly turned to technological interventions, particularly in environments where manual invigilation is insufficient or impractical. However, most existing tools focus on biometric verification, behavioral surveillance, or device based monitoring rather than addressing physical cheating aids that exploit invisible materials or micro scale design. Closed Circuit Television (CCTV) systems, often enhanced with artificial intelligence, have become standard in many exam halls. These systems enable real time behavioral analysis, facial recognition, and post exam review of suspicious activity. Kumar *et al*. (2022) proposed an AI based monitoring framework that flags behavioral anomalies during assessments (1). Despite their effectiveness in macro level supervision, such systems are infrastructure heavy and fail to detect low visibility or passive forms of cheating such as UV inks or slips hidden beneath clothing.

Radio Frequency Identification (RFID) and Near Field Communication (NFC) based systems offer reliable means of candidate authentication and attendance tracking (2). While helpful in verifying identity and location, they cannot identify physical cheating materials like printed slips or hidden writing. Likewise, metal detectors and body scanners focus on electronic devices and metallic objects, producing false alarms in the presence of benign accessories and overlooking non metallic contraband.

Manual inspection using UV flashlights has been employed for ink detection in security and authentication contexts (3), but such methods are heavily operator dependent and unsuitable for fast paced examination environments. Moreover, they lack contextual intelligence to distinguish between legitimate and illicit markings. Advancements in computer vision have introduced more robust possibilities for automated detection. Open source libraries like OpenCV provide tools for edge detection, morphological processing, and contour analysis.

These techniques, however, are often designed for controlled environments—such as document scanners or flat surfaces—and struggle with the variability presented by human skin, folds in fabric, or ambient lighting. Many of these systems are also designed for desktop platforms, limiting their portability and responsiveness in real time examination settings (4)(6). Commercial portable scanning devices, such as barcode and thermal imagers, offer real time image acquisition but are domain specific and lack the spectral flexibility required for ink differentiation. Most are not equipped to perform under varied illumination or identify low contrast markings across diverse substrates.

Taken together, the current landscape shows a clear gap: the need for a low cost, real time, embedded solution capable of detecting concealed ink based cheating materials in dynamic examination contexts. The proposed handheld multispectral scanner addresses this gap by merging portability, multispectral imaging, and embedded AI driven analysis into a single, examiner friendly tool.

METHODOLOGY

Block Diagram Overview: The proposed handheld multispectral scanner consists of seven integrated functional units, each playing a critical role in the real time detection of concealed ink. The system is structured for efficient coordination between hardware components, imaging modules, processing logic, and alert mechanisms.

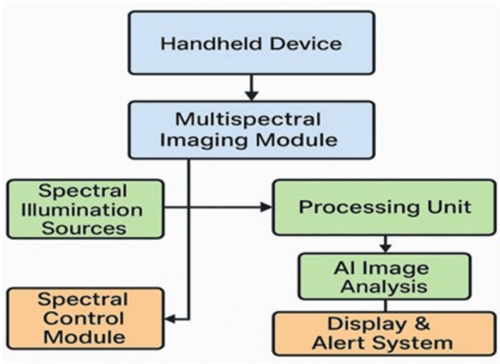


Figure 1. Block Diagram

Handheld Enclosure: This physical housing is designed to hold and protect all internal components while ensuring the device remains portable and user friendly. Its lightweight and ergonomic design makes it ideal for handheld operation during live examination monitoring.

Multispectral Imaging Module: At the core of the imaging system is the Pi Camera V2.1, strategically mounted within a ring of LEDs to maintain uniform lighting. This module captures a sequence of images under three different lighting conditions: white, ultraviolet (UV), and infrared (IR). The camera interfaces with the Raspberry Pi via the Camera Serial Interface (CSI), ensuring fast and high quality image transfer. (5)

Spectral Illumination Unit: This component includes an array of LEDs categorized into white (visible), UV (395–405 nm), and IR (~850 nm) sources. These LEDs are arranged concentrically around the camera lens to provide uniform illumination across the field of view. Each wavelength serves a unique detection purpose—UV highlights fluorescent inks, IR reveals absorbed ink residues, and white light serves as a visual baseline. (3)

Illumination Control Module: The lighting system is driven by control logic housed within the Raspberry Pi. This module uses MOSFET drivers or relays to toggle between different LED arrays in a timed sequence. The switching order—white, UV, then IR—is carefully synchronized with image acquisition to ensure that each frame corresponds to its respective illumination source. (5)

Processing and Control Unit (Raspberry Pi 4): The Raspberry Pi 4 functions as the central control unit, orchestrating all system operations. It manages LED sequencing, triggers the image capture process, runs real time image analysis, and activates output responses. The entire workflow is implemented using a custom Python script that coordinates hardware and software components (5).

AI Based Image Processing Engine: This module is developed using the OpenCV and NumPy libraries. It applies a combination of pre processing techniques—including noise reduction, adaptive thresholding, and frame differencing—to enhance detection accuracy. By comparing variations across the captured spectral images, the engine can isolate unusual markings that are otherwise invisible in normal lighting. Contour detection and edge based segmentation are used to locate text like patterns for further inspection. (6)

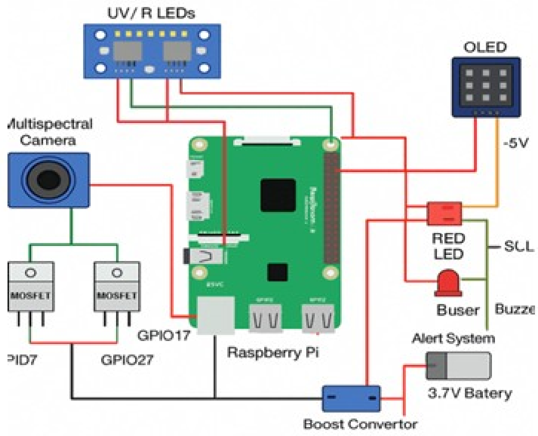


Figure 2. Circuit Design EDA

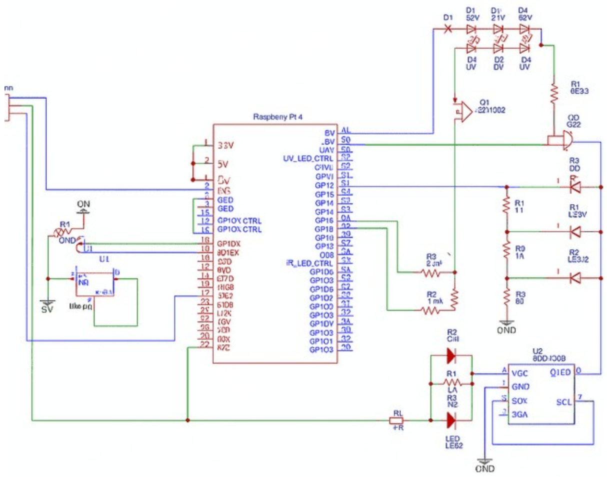


Figure 3. Circuit Design

Feedback and Alert System: To ensure prompt examiner response, the system includes an integrated alert mechanism consisting of LED indicators, a buzzer, and an optional display module (HDMI or TFT). When a potential ink detection is triggered, visual and auditory signals are immediately activated. The system can also archive flagged frames to a microSD card or USB drive for future review and validation.

System Workflow: The scanning process follows a structured sequence initiated by the examiner via a simple push button. Upon activation, the Raspberry Pi controls the illumination cycle, beginning with white light exposure, followed by UV and IR lighting phases. The camera captures a separate frame under each condition, which are then fed into the image analysis engine. The processing engine compares pixel level data across these images to detect anomalies—such as ink patterns that only appear under UV or IR. If any suspicious features are found, the device triggers alerts through the built in buzzer and LED system. Optionally, the detected frame is shown on a screen or saved for documentation. The complete workflow operates offline, ensuring independence from external networks or cloud based systems. (5) (7)

Hardware Components: The device is built using low cost, commercially available components. At its core is the Raspberry Pi 4 Model B, which handles image capture, logic control, and real time processing. A Pi Camera V2.1 provides high resolution imaging capabilities under three lighting-conditions. The illumination setup includes white LEDs for standard visibility, UV LEDs (395–405 nm) for detecting fluorescent inks, and IR LEDs (~850 nm) to identify markings that absorb infrared radiation. These are supported by driver circuits controlled through GPIO pins. Input is provided through tactile buttons, while output alerts are delivered using buzzers and LED indicators. Power is supplied by a 5V rechargeable battery, which supports the device's portability and field readiness. (5) (7)

Optical Illumination Strategy: To maximize ink visibility across spectral ranges, the system uses a sequential lighting approach. Each scan cycle begins with white light to establish a baseline image. UV light follows, revealing fluorescent or invisible inks, while IR illumination is used to detect inks that-absorb-infrared-wavelengths. Each phase in the cycle lasts approximately two seconds, enabling a complete scan in under six seconds. This controlled sequencing ensures effective contrast across varying materials and ink types, including those obscured by clothing or skin tone.

Image Capture and Preprocessing: During each scan, the camera captures one image per lighting mode. These images are processed in real time using OpenCV. First, they are converted to grayscale to reduce complexity in cross spectrum comparison. Gaussian blur is applied to minimize noise, followed by adaptive thresholding to highlight ink patterns against the background. Optionally, histogram equalization is performed to improve contrast in cases of uneven lighting. These preprocessing steps ensure the system can detect even faint or partially obscured markings. (6)

Feature Detection and Analysis: The processed images undergo further analysis to identify possible ink based content. The Canny edge detection algorithm outlines the boundaries of suspicious regions. Morphological dilation is used to connect fragmented ink strokes and enhance structural continuity. Contours are extracted and approximated into polygons to determine their similarity to text or handwriting. The system then applies bounding boxes and area filters to exclude noise and non text elements. If a contour is detected under UV or IR but not under white light, it is classified as concealed ink, triggering the alert mechanism.

Alert and User Interface: The scanner provides immediate feedback to the examiner upon detection. A buzzer sounds, and LEDs flash to signal a potential violation. Additionally, the flagged image may be displayed on a connected HDMI or TFT screen for verification. Each detection event is optionally stored with a timestamp for documentation and audit purposes. The interface is kept intentionally minimal to ensure usability by non technical users, such as invigilators.

Circuit Design: The circuit is designed for compact integration and energy efficiency. The Raspberry Pi GPIO pins control the UV, IR, and white LED arrays via MOSFET switches, enabling reliable high current operation. The Pi Camera connects via the CSI port for high speed data transfer. Input devices like buttons and output devices like the buzzer and LEDs are interfaced through digital GPIO pins. The complete circuit was designed using EasyEDA, ensuring proper schematic layout and trace routing suitable for PCB fabrication (5).

Software Stack: The proposed system is powered by a lightweight yet robust software stack optimized for real time embedded vision tasks. Python 3.11 serves as the primary programming environment, offering simplicity and cross platform compatibility. Core image processing functions, including filtering, thresholding, and contour detection, are implemented using OpenCV 4.x, a powerful computer vision library.

Hardware level control, such as switching LEDs and reading inputs from buttons, is managed through the RPi.GPIO library, which provides direct access to the Raspberry Pi's GPIO pins. For image enhancements such as resizing and annotation, the system uses Pillow, a flexible imaging library that integrates well with Python and OpenCV. (6) (5) (4)

Advantages of the Proposed System: The handheld scanner offers several compelling advantages that make it well suited for examination security. Its core strength lies in multispectral detection, which enables the identification of ink patterns invisible to the naked eye by leveraging UV and IR illumination. The system supports real time processing, allowing examiners to receive immediate alerts with minimal latency.

Designed for field use, the device is highly portable, compact, and lightweight, making it ideal for handheld operation in crowded exam settings. Furthermore, the entire system is cost effective, utilizing readily available off the shelf hardware components without sacrificing performance or reliability. (7)

Implementation and Experimental Evaluation: To validate the effectiveness of the proposed scanner in real world examination conditions, a series of structured experiments were conducted across various materials and ink types. The evaluation focused on the system's ability to detect concealed markings on skin, paper, and fabric using multispectral imaging under visible, ultraviolet (UV), and infrared (IR) light. These tests replicated common scenarios observed in examination settings, such as hidden ink on palms, beneath clothing, or embedded within notebook covers. Fifty sample cases were prepared using combinations of visible ink, UV reactive invisible ink, and IR absorbent substances such as charcoal or carbon based compounds. Surfaces included standard A4 paper, light cotton fabric, and the human forearm to simulate concealment scenarios.

All tests were conducted under typical indoor fluorescent lighting (300–500 lux) to reflect realistic classroom conditions. The scanner was operated in handheld mode by a test examiner, with the scanning head held approximately 10–15 cm from the target surface. Under white light, the scanner captured baseline imagery for comparison. UV illumination successfully revealed fluorescence from otherwise invisible ink on paper and skin, while IR imaging effectively exposed IR absorbing materials even beneath thin clothing. In some cases, printed watermarks caused minor false positives, but these were rare and easily resolved during review.

The average scan time was approximately 1.2 seconds per target, with immediate audio visual alerts issued upon detection. Images revealed clear distinctions between concealed and legitimate markings, supporting accurate examiner judgment without requiring external processing.

The device demonstrated strong detection capabilities with an overall accuracy of 96% across all test conditions:

Figure 4. Visible ink on paper: 100% – Captured clearly under white light UV reactive ink on skin: 94% – Minor variability due to motion blur IR absorbing ink beneath clothing: 91% – Effective; some background interference Printed patterns (e.g., watermarks): ~96% – Occasional false positives in IR view

- Visible ink on paper: 100% – Captured clearly under white light
- UV reactive ink on skin: 94% – Minor variability due to motion blur
- IR absorbing ink beneath clothing: 91% – Effective; some background interference
- Printed patterns (e.g., watermarks): ~96% – Occasional false positives in IR view

To assess practical usability, a mock examination simulation was conducted with 10 student volunteers. Each participant concealed markings using either invisible ink or slips beneath their clothing. The handheld scanner successfully detected all concealed content within seconds of activation, confirming its real time detection capability. The intuitive design and automated alert mechanism ensured smooth operation by the examiner without requiring any specialized training.

CONCLUSION

This study presents a novel, portable solution to the growing issue of ink based cheating in academic assessments. By integrating multispectral imaging with embedded image processing, the proposed scanner addresses a critical gap in current examination security systems. Unlike traditional invigilation methods, the scanner operates offline, requires no internet connectivity, and provides immediate alerts without relying on human interpretation. Through extensive testing, the system has shown its effectiveness in detecting both visible and invisible ink across varied surfaces with high accuracy. Its affordability, compactness, and ease of use make it an ideal tool for institutions aiming to reinforce examination integrity with minimal disruption to existing processes.

Future Scope

While the current system performs effectively in controlled academic scenarios, several enhancements are planned for future iterations. Integration of lightweight deep learning models such as MobileNet or Tensor Flow Lite could automate ink classification and improve detection accuracy across diverse handwriting styles and ink types. Battery optimization and ergonomic redesign could further increase portability and usability in large scale deployment. In addition, environmental sensors may be incorporated to adapt image capture settings to ambient lighting. Data logging with secure timestamps and optional cloud synchronization could enable the scanner to function as both a real time monitoring tool and a post exam audit resource. These enhancements would contribute to making the scanner an indispensable asset for secure, fair, and transparent academic assessment.

REFERENCES

Kumar, R. *et al*., "Real time AI based Behavior Monitoring for Exam Security," IEEE Access, vol. 10, pp. 13240–13252, 2022.

Singh A. and S. Rao, "NFC based Smart Attendance and Access System in Examination Halls," International Journal of Computer Science and Information Technologies (IJCSIT), vol. 12, no. 3, pp. 201–206, 2021.

Zhang, Y. M. Li, and L. Wu, "UV Responsive Ink for Covert Marking and Authentication," Journal of Photonic Science, vol. 17, no. 4, pp. 354–361, 2020.

Bradski G. and A. Kaehler, *Learning OpenCV 3: Computer Vision in C++ with the OpenCV Library*, Sebastopol, CA, USA: O'Reilly Media, 2016.

Raspberry Pi Foundation, "Raspberry Pi 4 Hardware Documentation," Raspberry Pi, 2023. (Online). Available: https://www.raspberrypi.org/documentation/

OpenCV Developers, "Image Processing Techniques and Contour Detection," OpenCV Docs, 2023. (Online). Available: https://docs.opencv.org/

Tiwari P. and S. Deshmukh, "Multispectral Image Processing for Ink Differentiation," International Journal of Computer Vision and Pattern Recognition (IJCVPR), vol. 9, no. 2, pp. 101–108, 2019.

****