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Digital Signal Processing and Machine Learning for Exam Fraud Detection

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Abstract

One of the main issues that presents difficulty in online learning settings is academic dishonesty. In these environments, traditional proctoring techniques are not always successful; hence, a new hybrid system is under development to address the problem. This creative system detects cheaters in the act by combining digital signal processing and image processing. Multiple cameras in the image processing component of the system monitor students during tests and flag any suspicious activity, including too forceful hand gestures or head movements. Simultaneously, the digital signal processing element finds any illegal devices and blocks internet access to stop digital cheating. Under tests, the system produced some rather outstanding results. It was 100% successful in blocking internet access and able to correctly identify illegal devices 96% of the time and aberrant physical movements 80% of the time. Over current approaches that only use one of these techniques, the twin approach of tracking behaviour and identifying devices represents a significant improvement. The system still has certain constraints and is not flawless, though. The accuracy rate falls to 65% in noisy or complicated surroundings, which emphasises the need for more improvement. Schools and colleges wishing to put sensible plans into action to stop cheating and uphold academic integrity will find great use for this study.

Keywords: *Proctoring System, Academic Integrity, Digital Signal Processing, Image Processing, Exam Fraud Detection*

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1. Introduction

Exam academic dishonesty has become a major issue, particularly given the quick move to online and remote learning settings. Academic assessments' integrity is sometimes compromised as students use subtle physical motions and digital devices to cheat—usually avoiding conventional proctoring techniques. The growing acceptance of digital tests following the COVID-19 epidemic has aggravated this problem since it presents major challenges to guaranteeing fairness and trust in academic assessments (Dendir & Maxwell, 2020).

Both manual and automated existing proctoring systems sometimes fail in identifying advanced forms of cheating, especially in remote locations where students may use their surroundings or access outside resources to hide their activity. Many studies have underlined these restrictions, showing that unproctored tests are much more likely to be cheated on than proctored ones, so stressing the need for strong monitoring systems (Fendler et al., 2024). Furthermore, proctoring systems could raise questions about justice and privacy since some students say their anxiety under monitoring rises (Lee & Fanguy, 2022).

This work presents a hybrid proctoring system combining advanced image processing methods with digital signal processing (DSP) to solve these challenges. Superior to conventional and single-method solutions, this combined approach improves the scalability, dependability, and adaptability of proctoring systems. Unlike traditional systems, the suggested architecture is meant to run efficiently in challenging surroundings while addressing typical constraints, including background noise and connectivity problems. Previous research has shown how well image processing methods might identify suspicious behaviour including too strong gestures or head movements, which might point to illegal activity. For instance, systems based on convolutional neural networks (CNN)-based have shown promise in spotting such behaviours during online exams (Lee & Fanguy, 2022). But problems like false positives brought on by non-static objects or lighting variances have reduced the potency of these techniques (Tweissi et al., 2022). In proctoring, similarly, the illegal use of mobile devices for internet access or external communication continues to be a major issue. Using device identification technologies, among other signal-based detection systems, has shown promise in identifying and blocking illegal devices during tests (Raj et al., 2015). Many current methods, meanwhile, lack the resilience required to keep accuracy in dynamic, resource-intensive environments (Das, 2015).

This work intends to close these gaps by means of DSP technologies' integration with image processing to create a complete cheating detection system. Combining these methods results in a suggested system with advanced noise reduction techniques and real-time signal detection and blocking capabilities, so improving detection accuracy. Furthermore, the answer is meant to handle other high-stakes environments, including standardised testing centres and professional certification tests, where preserving

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academic integrity is critical (Wakchaure et al., 2023). All things considered, this study advances proctoring technologies by providing a scalable, dependable, flexible solution that tackles both digital and physical forms of cheating. This study offers insightful analysis for educational institutions and companies trying to maintain academic integrity in an increasingly digital environment by addressing the constraints of current systems and extending its application to high stakes testing environments (Nguyen et al., 2022).

2. Literature review

For years, academic dishonesty detection and prevention have presented a difficulty for educational institutions during tests. As online and remote learning have grown, cheating strategies have changed, and advanced proctoring technologies are needed. Effective in physical environments, traditional manual monitoring suffers with scalability and adaptability in remote environments, hence creating an urgent need for automated solutions including technologies such as image processing, machine learning (ML), and digital signal processing (DSP) (Nigam et al., 2021).

2.1. Wider Ramifications of Proctoring Technologies

Advanced proctoring technologies have important ramifications for student trust, fairness, and academic integrity. Although these technologies improve exam security, their acceptance also begs questions about fairness, privacy, and the general student experience. Studies show that too much monitoring during tests can cause stress and anxiety in students, so maybe compromising their performance (Lee & Fanguy, 2022). Such stress can undermine the supportive environment required for fair assessments, so raising issues regarding the ethical balance between preserving academic integrity and guaranteeing student welfare.

Institutions also must negotiate the concept of fairness since too close observation could be seen as invasive or suspicious. Dealing with these more general consequences means that institutions must balance strong security policies with creating an environment that supports academic development and confidence. Beyond education, the uses of these technologies span corporate training and certification tests, where upholding integrity is equally crucial (Nigam et al., 2021).

2.2. Psychological and Ethical Considerations

The psychological and ethical effects of proctoring technologies are still little investigated in the body of current research. Although efficient monitoring depends on technical developments including image processing and DSP, they raise privacy, data security, and algorithmic fairness issues. Detection systems, for instance, might show prejudices that disproportionately impact particular demographic groups, so casting doubt on equality and inclusivity (Archer, 2023).

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Studies also highlight the psychological toll that continuous monitoring during tests takes, which might compromise the learning process. In such environments, students sometimes report feeling nervous or unfairly examined; this could lower their performance and general confidence in the education system (Kuleva & Miladinov, 2024). Reducing these problems calls for both ethical frameworks like privacy by design and the ideas of ethical artificial intelligence. Institutions can reduce unintended consequences and maintain exam integrity by including justice and inclusivity in algorithm development. Ethical frameworks such as privacy by design and the principles of ethical AI are essential for mitigating these issues. By embedding fairness and inclusivity into algorithm design, institutions can minimize unintended consequences while preserving the integrity of exams.

2.3. Novel AI Methodologies and Their Possibility

Rising artificial intelligence methods, including deep learning, federated learning, and reinforcement learning, present interesting answers to close current gaps. By processing vast datasets and spotting subtle behavioural patterns, deep learning models—even in challenging environments—can raise detection accuracy (Nigam et al., 2021). By keeping sensitive student data on local devices instead of centralised servers, federated learning helps to enable distributed training of models, so lowering privacy issues. Dynamic responses to unforeseen events, such as spotting new cheating techniques (Nigam et al., 2021), can be made possible by reinforcement learning's real-time adaptation of proctoring systems. These developments not only solve technical problems but also offer a structure for scalable ethical proctoring technologies. Adaptive learning systems can, for instance, personalise the proctoring experience to reduce stress while preserving strong security. Including such theoretical frameworks into the proctoring system design guarantees a more comprehensive approach to handling the several issues of exam integrity (Slusky, 2020).

3. Method

This work proposes an integrated system to detect and stop cheating during tests by combining digital signal processing (DSP) with convolution matrix-based image processing. While the DSP module deals with the detection and prevention of illegal device use, the image processing module concentrates on observing physical behaviors including head motions and gestures. To assess its scalability, dependability, and efficacy, the system was thoroughly tested under several settings. Together with thorough approaches and performance criteria, below is a summary of every element together with their importance.

3.1. Image Processing via Convolution Matrices

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Designed to track participant behavior across several video feeds, the image processing module was meant to spot possible cheating activities, including too frequent head turns or hand gestures. This element guarantees a thorough examination of participant actions to uphold exam integrity in both static and dynamic surroundings.

3.1.1. *Multi-Camera Arrangement and Video Data Collecting*

To guarantee complete exam room coverage and minimize blind spots, a multi-camera system was used to record video feeds from several angles. Strategically positioned cameras with a frame rate of 30 fps and a 1080p resolution were meant to monitor participants efficiently (see Figure 1). Real-time processing of these feeds allowed the identification of aberrant movements suggestive of cheating.

3.1.2. Preprocessing and Background Subtraction

To cut computing complexity, the raw video data was converted to grayscale. Participants were separated from their surroundings using a background subtraction technique (such as Mixture of Gaussians), so reducing background object or lighting variation interference. This preprocessing step lowered false positives brought on by complex or dynamic backgrounds.

3.1.3. Convolution Matrix for Motion Detection

Using a convolution matrix, every video frame was examined to find motion depending on pixel value changes and edge highlighting. This method helped to identify odd actions, including hand gestures or repeated head turns. Integration of data from several camera angles helped to lower false positives resulting from single-camera viewpoints and enhance detection accuracy.

3.1.4. Adaptive Thresholds for Suspicious Behavior Detection

Adaptive thresholds were developed to separate suspicious behavior from regular exam activities, including writing or posture corrections. Data on participant behavior gathered during simulated tests informed these thresholds, so they served as a baseline for normal activity. Environmental elements—including lighting, background complexity, and camera placement—also affected changes made. Furthermore, machine learning techniques were used to dynamically change the thresholds in real-time during tests, so allowing for environmental changes, including unanticipated background motions or abrupt lighting changes.

3.1.5. System of Alertness

The system created real-time warnings to alert proctors when participant movements exceeded adaptive thresholds. These alarms maintained a record for post-exam analysis and allowed instant intervention by marking video sections for review.

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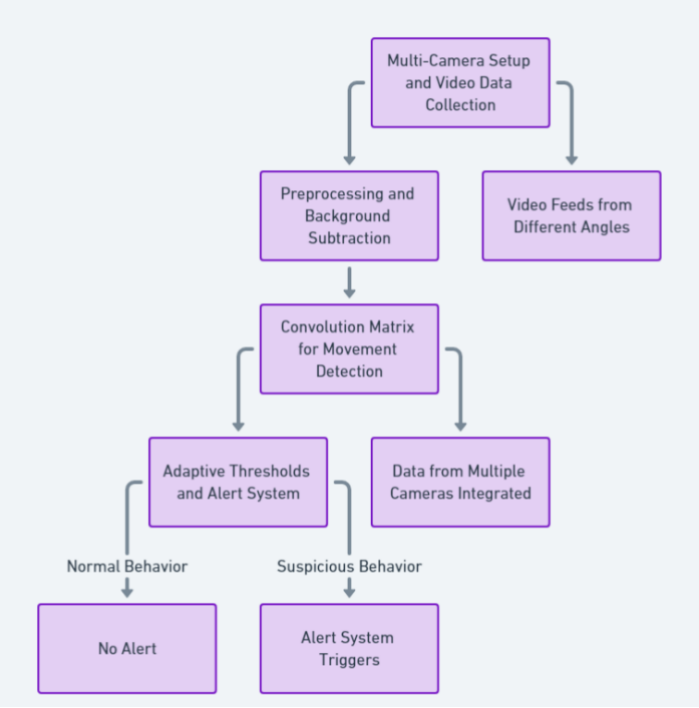

Figure 1. *System of video monitoring and cheating detection: workflow*

Figure 2. *Exam room motion detection multi-camera placement layout*

3.2. Digital Signal Processing for Device Detection

The DSP module was made to find and stop the usage of illegal devices during tests. This part concentrated on spotting cellphones and blocking internet access to reduce digital cheating

3.2.1. IMEI Detection via RTL Decoder

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Placed all around the exam room, signal sensors ranging in sensitivity from 900 MHz to 2.4 GHz picked up radio frequencies emitted by mobile devices. Finding IMEI numbers, the RTL decoder cross-referenced them with a database of approved devices. Real-time flagging of any illegal device was sent to proctors.

3.2.2. Signal Jamming for Internet Blocking

Wi-Fi and cellular networks (3G, 4G, 5G) were blocked using a signal jammer to stop access to internet resources. Operating inside a 10-meter radius, the jammer dynamically changed its frequency to stop attempts at bypass. Every effort to establish connections to blocked networks was recorded for inspection.

3.2.3. Testing and Reviewing

Under three conditions—controlled environments, which included static rooms with minimal background activity; dynamic environments, which included exam rooms with moving objects, varied lighting, and high participant activity; and low-light conditions, meant to replicate poor lighting scenarios to test the system's resilience—the DSP module was assessed. Performance measures included the accuracy of suspicious movement detection, measured as the percentage of correctly flagged actions against total flagged actions; the dependability of IMEI identification, assessed by the percentage of correctly identified devices against the total number of detected devices; and the efficacy of signal jamming, evaluated based on the percentage of devices unable to access the internet during exams. Each testing condition consisted in ten controlled and dynamic environments with twenty participants and ten devices for DSP evaluation.

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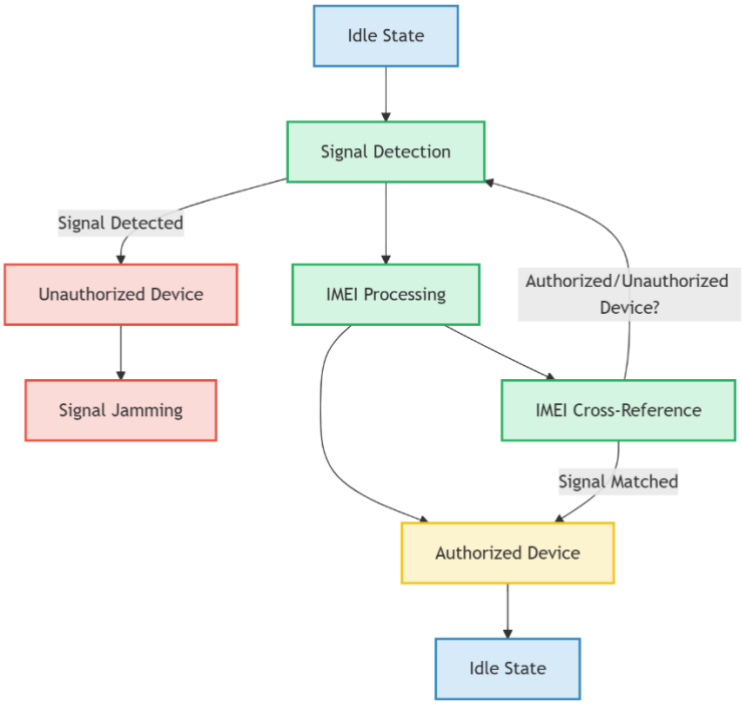

Figure 3. *IMEI signal detecting and authorisation flowchart*

3.3. Ethical Questions

The study guaranteed adherence to privacy rules and ethical guidelines to solve possible ethical questions. Before the tests, written permission was obtained from every participant; video and signal data were anonymized to avoid person identification. Careful configuration of the signal jammer allowed it to run at frequencies free of interference with medical or emergency devices, so reducing intrusion. Furthermore, detection algorithms were tested for biases and optimized to guarantee fair treatment of all participants, regardless of demographic background.

4. Findings and discussion

To solve the difficulties preserving exam integrity in both stationary and dynamic environments, this work assessed the efficiency of a hybrid cheating detection system integrating convolution matrix-based image processing and digital signal processing (DSP). The results are shown here; next is a thorough analysis of their limitations and ramifications. Performance of the Image Processing Module

Under controlled, stationary environments, the image processing component attained 80% accuracy in identifying suspicious motions. Accuracy dropped to 65% in dynamic settings, which are defined by intricate backgrounds and changing lighting, so underscoring the difficulties of environmental noise and inconsistent lighting conditions.

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Although background subtraction and adaptive thresholds helped to somewhat address these problems, dynamic elements caused false positives and undetectable behaviour to continue.

4.1.1. DSP Module Performance

With the IMEI detection system attaining 96% accuracy in spotting illegal devices under all testing conditions, the DSP component regularly showed great dependability. This robustness is ascribed to the relative insensitivity of signal-based techniques to environmental variables as opposed to visual data. The signal jammer also proved 100% efficient in blocking Wi-Fi and cellular networks, so guaranteeing that no device could connect during the tests.

4.1.2. Statistical Metrics and Analysis

Precision, recall, and F1 scores were among the statistical tools used to gauge the system's performance. Computed using confusion matrix evaluations of true positives, false positives, and false negatives, the F1 score for image processing was 0.82 in static conditions and 0.67 in dynamic conditions. These results show how well the system strikes a mix between recall—detecting actual cheating—and accuracy—minimizing false positives. Variance analysis revealed notable performance variations between static and dynamic environments ($p < 0.05$), so underlining the impact of environmental complexity.

4.1.3. *Table 1's Summary of Results*

Table 1 summarizes the performance data such that the effectiveness of the system across several components and conditions is amply evident.

Table 1. *Hybrid Cheating Detection System Percentage-Based Performance Results*

Attribute	Percentage Performance (%)
Image Processing (Static Conditions)	80% accuracy in spotting suspicious motions
Image Processing (Dynamic Conditions)	65% of accuracy in spotting suspicious motion.
DSP Component (IMEI Detection)	96% accuracy for spotting illegal devices
Jammer of Signatures	Perfect efficiency in filtering cellular networks and Wi-Fi
F1 Grade under Static Conditions	82% (versed from 0.82)

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F1 Score Based on Dynamic Conditions	67% (derived from 0.67)

4.2. Discussion

4.2.1. Respecting the Research Objectives

Through addressing both physical and digital cheating issues, the hybrid system successfully meets the research goals stated in the introduction. While the DSP component consistently detects and stops illegal device use, the image processing module offers real-time observation of participant behavior. These modules taken together offer a scalable, integrated method of proctoring that improves exam integrity in many contexts.

4.2.2. *Concerning Educational Institutions*

Particularly in remote and hybrid learning environments, the results have major ramifications for educational institutions. The strong performance of DSP techniques shows that these systems can be easily applied to guarantee digital tests. Although efficient in stationary conditions, the image processing module emphasizes the need of constant improvement to operate consistently in dynamic environments. Institutions must take hardware (e.g., cameras, signal sensors), software development, and training proctors into account for practical adoption if they are to properly use the system.

4.2.3. Restraints and Future Orientations

Although the system shows promise, a few drawbacks were noted:

1. Environmental Sensitivity of Image Processing**:** Advanced noise-handling methods are clearly needed based on the declining accuracy in dynamic environments. Deep learning techniques, including convolutional neural networks (CNNs) could be included in future research to increase detection accuracy by means of better noise reduction and context-aware analysis.
2. Real-time processing of video and signal data calls for major computational resources. Priority remains optimizing algorithms for efficiency without sacrificing performance.
3. Two important ethical issues are data security and privacy. Emphasized should be measures like anonymizing video data, getting informed permission, and making sure signal jamming follows legal criteria. Future research should investigate the moral consequences of implementing such mass-based systems, including possible algorithmic biases in detection.
4. While the DSP module performed well, bypass techniques, including VPNs and low-power networking technologies, demand constant monitoring and updates to stay effective.

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4.2.4. Applications Outside of the Classroom

The system's adaptability reaches beyond classroom environments to include corporate training, centralised testing facilities, and professional certification exams. Its scalability and value across sectors where preserving assessment integrity is essential are improved by this more general applicability.

5. Conclusion

This work develops a hybrid system combining digital signal processing (DSP) and image processing to solve the problem of exam cheating in remote and hybrid learning environments. The aim was to design a system able to identify and stop digital as well as physical cheating where conventional proctoring techniques are insufficient. The system apparently combines these technologies rather well. While performance dropped to 65% in more dynamic environments, indicating the need of improved noise reduction and customization, the image processing module achieved 80% accuracy in controlled settings, spotting behaviors like suspicious head motions. DSP techniques, meantime, were quite dependable; they blocked internet access 100% and detected illegal devices with 96% accuracy.

This hybrid system presents a scalable approach to raise digital exam academic integrity. While the image processing module shows promise but requires more improvement for complicated conditions, the DSP components are immediately useful for securing exam environments. Adopting such systems helps educational institutions gain from more fair assessments, less cheating, and more confidence. Still, issues with cost, scalability, privacy, and user training must be resolved.

Future studies should concentrate on enhancing the image processing module using convolutional neural networks (CNNs) using deep learning approaches to manage dynamic surroundings better. Combining several detection techniques—such as audio and visual analysis—may help the system to be even more successful. Maintaining these systems as ethical, fair, and privacy conscious depends on cooperation among researchers, institutions, and legislators. In progressively digital learning environments, these initiatives can help to preserve academic integrity while preserving trust and fairness.

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