ProctorEdge: Advanced AI Examination Monitoring and Security System

Neeraj S, Kollipara Rohith and Ani R
Department of Computer Science and Applications, Amrita School of Computing, Amrita Vishwa Vidyapeetham, Amritapuri, India

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Abstract: Rapid development of artificial intelligence and deep learning technologies has strongly transformed the online examination scenario in light of ensuring academic integrity. This paper presents an automated AI proctoring system that utilizes computer vision with facial recognition, smartphone detection, and audio detection techniques for monitoring a student's action during online assessments. These technologies are supposed to be integrated in order to implement a system that can detect suspicious behaviors and cheating behaviors during remote exam ination. This research goes through the methodologies involved, challenges, and further enhancements needed for improving the accuracy and efficiency of proctoring systems. This work thus becomes an all-inclusive guide for educators and developers on how to fully implement some practical online proctoring solutions in educational settings.

1 INTRODUCTION

Online exams are increasingly becoming the norm and, therefore, very convenient and flexible for the student and instructor. However, online exams also come with their chal lenges, such as integrity. Online exam cheating and academic dishonesty can invalidate assessments of learners, thereby undermining the entire education process. Our project has been centered on developing a robust proctoring system that would apply facial recognition technology, audio identification, and device detection to monitor and deter online exams cheating.

Key Features:

1. Facial Recognition: The system uses facial recognition technology to authenticate the student sitting for the examination to make sure that the person sitting to attempt the test is the correct person.
2. Audio Identification: Through the recognition of sounds in the surrounding environment, the system checks if the student uses any other device or communicates with someone during the examination.
3. Device Detection: The system checks if any additional devices have been connected or are being used by the student during the examination, triggers proctors to potential cheating behavior.
4. Tab Monitoring: The system tracks the browser tabs open on the student's device and alerts the proctor if any unauthorized tabs are found.
5. Alerts-Real time: Provide a real-time alert system such that the proctor becomes informed in real time as to any suspicious activity within their assigned exam, hence prepared to intervene at all times.

2 RELATED WORKS

Online student authentication and proctoring system based on multi modal biometrics technology (Labayen et al., 2021) advocates the use of an online proctoring system designed to monitor students taking the examination with commercial solutions such as continuous biometric recognition by way of face, voice, and typing. Secure authentication is guaranteed by gathering data from webcams, microphones, and keyboards in cloud servers that then match the data with various models of biometrics. Human supervision may be dispensed with at some levels due to the advanced use of AI algorithms for error-correcting capabilities over conditions. Future improvements could include student recognition with other devices when taking tests.

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Automated proctoring system using computer vision techniques (Maniar et al., 2021) is a proctoring system. The system has features of eye gaze tracking, mouth detection, object detection, head posture estimation via facial landmark detection. Further, the system transcribes the audio recording of the student voice into text using the Google speech recognition API, to detect conversations. The techniques used mostly are: biometric recognition (face recognition, eye gaze tracking, mouth detection, head pose estimation), object detection, cloud storage. The system used dlib's pre-trained network for real-time eye tracking and head pose detection. Challenges include accurate eye tracking and head pose estimation. Although the system alerts multiple persons, it does not provide continuous identity verification. The future upgrades can also include the detection of other devices and continuous student authentication.

ProctoXpert–An AI Based Online Proctoring System (Chougule et al., 2024) outlines a proctoring system using AI for face recognition, audio detection, and biometric authentication with live monitoring for anomaly detection. It supports post-exam review with encrypted data for security. The key methodologies include AI-based biometric recognition, misbehavior detection, and facial/audio analysis using Convolutional Neural Networks (CNNs) for tracking head position and eye movement to monitor the student's screen view. While the system benefits from AI-driven accuracy, challenges remain in detecting lighting conditions and background noise. Future enhancements may focus on identifying device use and improving additional monitoring data accuracy.

An incremental training on deep learning face recognition for M-Learning online exam proctoring (Ganidisastra and Bandung, 2021) elaborates on the accuracy issues that exist in today's proc- toring-based face recognition systems, and more specifically about the system's performance during the illumination change and minimal changes to the facial structure. The paper points out the pros and cons of these techniques by testing four face detectors; including Haar-cascade, LBP, MTCNN, and YOLO- face, along with testing one Facenet model. A deep learning-based face detector is better than the earlier methods. The Facenet model, which was batch trained, resulted in 98% accuracy but, in this incremental training version, the dataset is quite smaller. Viola-Jones/Haar-cascade : A traditional approach, based on integral images and Adaboost classifiers but poses and lighting variations affect significantly. Local Binary Pattern (LBP) : Makes local texture de-scriptions but is posing and lighting challenging. Multi-Task Cascaded CNN (MTCNN) : This has three stages of CNN to efficiently generate candidate windows and enhance face detection with the preservation of real-time performance YOLO-face : Deep learning algorithm based on YOLOv3; specially optimized for high precision face detection with very rapid speed in detection.

Multiple instance learning for cheating detection and localization in online examinations (Liu et al., 2024) presents CHEESE, an advanced cheating detection framework utilizing multiple instance learning to improve upon existing proctoring systems. It integrates body posture, background, eye gaze, head posture, and facial features through a spatio-temporal graph module, achieving an AUC score of 87.58 on three datasets. Key challenges addressed include video anomaly detection, with the Multiscale Temporal Network (MTN) capturing temporal dependencies in video clips. CHEESE consists of a label generator that produces anomaly scores using multiple instance learning and a feature encoder enhanced by C3D or I3D models, incorporating a self-guided attention module. This framework combines features from OpenFace 2.0 and C3D/I3D to analyze candidates' behavior holistically. Future enhancements may focus on detecting unauthorized devices used during exams and generating alerts.

A Systematic Review of Deep Learning Based Online Exam Proctoring Systems for Abnormal Student Behaviour Detection(Abbas and Hameed, 2022)discusses the challenges of ensuring academic integrity in online exams, highlighting the need for advanced technologies like deep learning to monitor abnormal student behavior. It investigates the effectiveness of deep learning algorithms in detecting cheating during assessments through a systematic literature review of 137 publications, narrowing down to 41 relevant studies on AI-based proctoring systems. The research identifies a key limitation: existing proctoring systems cannot fully prevent all cheating methods due to their evolving nature, necessitating ongoing improvements. Benefits of deep learning include enhanced detection capabilities and better exam security, while drawbacks involve technical challenges and privacy concerns

AI-based online proctor- ing system (Aurelia et al., 2024) addresses the need for proper online assessment methods that result in a rise of AI-powered proctoring services. The proposed work here is on developing a visual proctoring system based on webcam input, with emotion detection, head movement detection, and unauthorized objects that occur during exams using facial expression recognition with convolutional neural networks. The system improves monitoring and automates suspicious behavior detection but is likely to require human intervention and could possibly generate false positives. Further improvements will be made towards refining AI algorithms for more accuracy. The goal here is to develop a dependable proctoring system that ensures integrity in online examination settings.

AI based Proctoring System – A Review (Paul et al., 2024) discussed the necessity of improving security and integrity in online examinations more than ever with the introduction of the latter. It introduces an AI-based proctoring system, monitoring students remotely from a remote location via webcam while attempting an online exam using computer vision and machine learning. The key technologies are facial recognition, eye tracking, and keystroke analysis, which can identify behaviors linked to cheating. The study applies both qualitative and quantitative research methods in evaluating the performance of the system. The system, with its benefits of live monitoring and enhanced security of exams, presents several concerns over privacy and data protection. Future updates might be able to result in higher detection rates and user-friendliness. The key goal is to develop a reliable AI proctoring system to ensure cheating is completely prohibited and exams are held without any incidence of cheating for academic institutions.

Analysis on AI Proctoring System Using Different ML Models (Sharma et al., 2024) focuses on the need for effective proctoring techniques in Even with the COVID- 19 pandemic, online exams became the new norm for education. In this development, the use of AI- based proctoring techniques that were based on screen capture, keyboard analysis, facial recognition, and algorithms in detecting suspicious activity was highlighted. YOLO object detection for real-time object identification and FaceNet for facial recognition were suggested for usage. The system ensures more secure exams through automatic monitoring, though issues overlap against false positives. It will be plus to privacy. Further advancements will enable it to add the detection mechanism of mobile devices; further improve the algorithms for better performance. The key is making an almost effective proctoring system that is ensured not to let the integrity of the exams compromised and will do better than what exists currently.

Automated smart artifical intelligence-based proctoring system using deep learning(Verma et al., 2024) addresses the emergent demand of effective online education and difficulties in fair and secure examination processes while conducting an examination online. It discusses building a complete proctoring system, using AI and deep learning technologies to watch test-takers during their exams. Some of the key features are user authentication, text and voice detection, active window detection, gaze estimation, and phone detection to detect possible cheating. The system employs Dlib's facial keypoint detector and OpenCV for movement tracking, while using YOLOv3 trained on the COCO dataset for identifying individuals and mobile devices in webcam streams. It uses supervised classification methods such as PCA and SVM for tasks such as mouth state identification and face spoofing detection. Though the suggested system enhances proctoring capacities and automates workloads, there are also such challenges as privacy concerns and continuous improvement. With algorithms further refined for more precise and efficient results, immediate feedback to instructors will now be possible regarding the online test-taker's behavioral and emotional responses during actual tests.

Face Verification Component for Offline Proctoring System using one-shot learning (Karthik et al., 2022), the authors present an offline proctoring system with one-shot learning, which identifies the identity through it, for reducing issues like seat-swapping and lighting variations. MTCNN has been utilized for face detection, and a pre-trained Siamese network is used for face verification with 83.65 percentage accuracy on different orientations. Yet, problems with extreme angles and false negatives persist; real-time optimization and further incorporation are possible future improvements.

Heuristic-Based Automatic Online Proctoring System (Raj et al., 2015) A heuristic-based proctoring system with anomaly detection and student monitoring during online exams. Main features include face detection, behavioral analysis, and continuous tracking of the candidate's screen view. Heuristics-Based Rules Detection The use of heuristic rules flags suspicious activities such as prolonged absence or unusual gaze patterns. While the system is significantly effective in anomaly detection, it has problems in handling diverse lighting and environmental conditions that make accurate detection challenging. Going forward, there would be scalability and false positives concerns in the behavioral detection aspect.

An Intelligent System for Online Exam Monitoring (Prathish et al., 2016) A multi-modal proctoring system that uses video, audio, and active window capture to detect malpractice is introduced. Such features include face detection, yaw angle estimation for head pose analysis, and audio variation tracking, integrated into a rule-based inference system. Such features identify misconducts such as multi-face detection, prolonged face disappearance, and irregular audio or window activity. However, the challenges are handling diverse scenarios and real-time implementation as it achieved 80 percentage accuracy during tests. Future improvements include further scalability and enhanced feature detection to enable even wider use.

Real time Face Detection and Optimal Face Mapping for Online Classes(Archana et al., 2022), the system used a combination of Local Binary Pattern Histogram (LBPH) and Convolutional Neural Networks (CNN) for face recognition with an accuracy of up to 95 percentage. The system consists of a web-based interface developed in the Django framework. A Haar-cascade classifier has been used for real-time face detection. Although the system has shown great accuracy and efficiency, some challenges like variations in lighting conditions and facial occlusions exist. Future improvements involve using better quality webcams along with diverse datasets that can enhance further reliability and accuracy.

Strategies for Improving Object Detection in RealTime Projects that use Deep Learning Technology(Abed and Murugan, 2023), Projects using Deep Learning Technology have made tremendous improvements by developing improved versions of YOLO, particularly in the form of YOLOv7 and YOLOv8. The best- known improvements are in speed and mAP, thus achieving a very high score of real-time applications. These developed models are optimized through PyTorch, allowing efficiency in training, fine-tuning, and deploying deep learning models. Among techniques involved data augmentation, class balancing, ensemble learning used to address various challenges and limitations, the challenges consist of unbalanced data sets; small object detection; varying lighting. Introduction of variations to the data set training it makes them quite robust as per different kinds of variations in reality. Class balancing ensures well performance of all kinds of models across categories and further proceeds with IoT integration so that this technology could better realize live implementation. overall system efficiency. Through IoT, the data transmission and processing will be much faster, and the performance will be more fluid. However, there are some critical issues like accuracy of small objects and changing light illumination within a short time span that need to be overcome.

3 METHODOLOGY

The proposed system is going to allow the best computer vision techniques amalgamate with the most advanced models of machine learning for online proctoring. Making it safe and efficient is possible. An important aspect of making up the system should comprise the facial identification of the examinee. It captures the face and even tracks the direction of sight and detection of instances wherein the candidate got diverted from viewing the screen through eye tracking. Audio detection will include all unauthorized and background noise which might be captured hearing them and lastly, device control for noticing any gadget outside such as mobile phones etc. All the techniques above are implicit in the hybrid technique. It's all-inclusive in such a way that it is easy to find and mark suspicious behaviors inside the hall of examination. Facial recognition establishes that the right candidate is present for the test while eye tracking and audio identification trace the cheating behavior by detecting gaze deviation, prolongation of distraction, or illegal communication. The device monitoring is recognition of any use of equipment to compromise the integrity of the examination.

The integration of the above technologies provides a safe, real-time monitoring solution to common problems that may arise in the remote proctoring setup, such as identity fraud, cheating attempts, and distracting external factors undermining the credibility and fairness of an online examination.

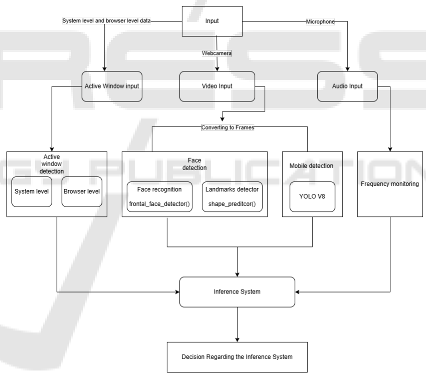

Figure 1: System Architecture

3.1 Facial Recognition

This module identifies the student using facial recognition and tracks eye movement to detect off-screen gazing.

3.1.1 Facial Landmarks Identification

The system captures face structures using Dlib precomputed models: This step identifies 68 crucial key facial landmarks in any subject's face which determine how to calculate their head direction and gaze. Nose point, eye-corns are captured along face-boundary.

3.1.2 Estimating Yaw Angles Calculations

It estimates the yaw angle using a head pose estimation technique with cv2.solvePnP(). It computes the 3D rotation of the head based on the relationship between predefined 3D facial points like the nose tip, eyes, and mouth corners with their corresponding 2D points in the image. The yaw angle as the head rotation around the X-axis horizontally is retrieved from the rotation vector as

$$yawangle = np.degrees(rotationVector[1])[0] \quad (1)$$

That is, rotation vector actually represents the yaw rotation component in radians, so this should be converted to degrees.

3.1.3 Extended Gaze Deviation Detection

When the yaw angle exceeds the defined thresholds, for example greater than the RIGHT YAW THRESHOLD or less than the LEFT YAW THRESHOLD, longer than the alert duration of 3 seconds is set and the system flags a warning. It is this that allows for prompt detection of prolonged distractions or looking away from the screen.

3.2 Smartphone and Tablet detection

This module determines the use of a smartphone or tablet through a mobile detection model. The YOLO version 8 was customized and fine tuned on a customized dataset of 3250 images. The training process included number of epochs = 55, batch size = 16 and image size = 640 pixels for accurate identification of a mobile device.

3.3 Audio Identification

The audio identification module continuously monitors the environment for unauthorized sounds, such as communication or external device usage. Using microphones connected to the student's device, the system analyzes audio data in real time to enhance the proctoring process.

3.3.1 Audio Monitoring

The system detects sounds above a predefined frequency threshold of 500 Hz, flagging them as suspicious and generating alerts for the proctor. This allows for immediate investigation of potential cheating incidents.

3.3.2 Frequency-Based Flagging

By applying a frequency-based method, the system ensures that only sounds indicative of potential cheating are flagged, effectively reducing false positives from normal environmental noise.

3.4 Tab Monitoring

3.4.1 Browser Activity Monitoring

The system uses the browser's APIs to track any attempt that the student makes to change tabs or open a new tab. In case the student opens an unauthorized tab, the system flags that particular action and notifies the proctor.

Table 1: Tab Monitoring APIs

API	Description
chrome.tabs.onActivated	To detect switching to a different tab
chrome.tabs.onCreated	To detect when a new tab is opened
chrome.tabs.onUpdated	To detect changes in a tab, such as a URL change

3.4.2 Real-time Tab Alerts

Anything the student does that has to do with opening an unauthorized tab will immediately be sent to the proctor's attention, meaning that the student cannot look up anything they are unsure about during the test.

3.5 Inference System

The outputs from audio capture, video input, and system usage are integrated into a rule-based inference system. These outputs are processed by the system, which classifies them to identify potential misconduct. The analysis combines all time frames where the yaw angle and audio output exceed the threshold value, along with any variations in window changes, to generate an output log. If any one of these factors is detected in a given time frame, it can indicate a potential for misconduct. The results highlight the likelihood of malpractice, along with the associated time frame

4 EXPERIMENTAL RESULTS

In this study, we deployed the pre-trained face and mobile detection models. We made use of the dlib library to perform the face detection as well as the localization of facial landmarks. For the face detection, we implemented the frontal face detector by dlib, while for the facial landmark detection, we used the "shape predictor 68 face landmarks.dat" model. The alerting system was set at a threshold of 3 seconds to detect prolonged gaze deviations and send alerts out whenever users look away from the screen for longer durations. In addition to tracking the user's gaze direction, the system efficiently detects the presence of multiple faces. This is crucial for proctoring scenarios, where the presence of additional individuals can indicate misconduct. The system raises an alert when more than one face is detected in the frame. For mobile detection, we employed a pre-trained object detection model YOLO version 8 that was fine-tuned on a custom dataset of smartphone and tablet images. This model was adapted to quite accurately detect mobile devices in real-time, enhancing the system's capability to monitor and alert when unauthorized devices are in use.

4.1 Face Detection Scenarios

A pre-trained model was run on various test scenarios to revalidate the accuracy in face detection and head orientation estimation. Test results showed reliable face detection and tracking during changes in position of the head

4.2 Yaw Angle Detection

The system calculates the yaw angle to detect whether the user is looking straight, to the left, or to right. The yaw angle threshold for detecting a left-ward gaze was set at -1° and for a right-ward gaze at -2°. This setup helped in precisely identifying if the user was looking sideways, allowing for timely alerts during instances of gaze deviation.

4.2.1 Looking Straight

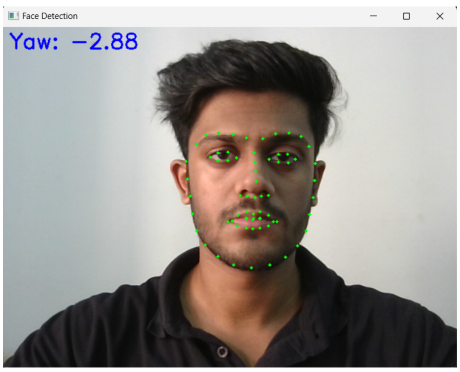

Figure 2: Yaw angle of face looking straight.

When The user's face is directly in front of the camera, indicating that the user is looking straight. The figure below demonstrates the output when the user is looking straight at the camera (see Fig.2).

4.2.2 Looking Left

When the examinee looked to the left, the system tracked the movement and calculated the yaw angle (see Fig.3).

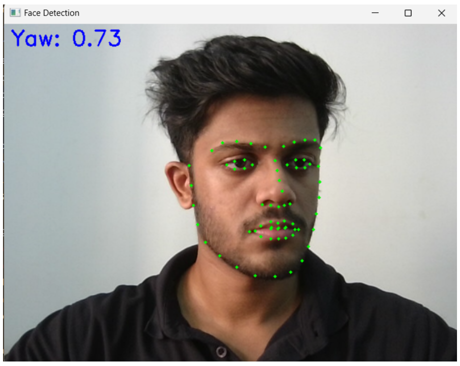

Figure 3: Yaw angle of face looking left.

4.2.3 Looking Right

When the examinee looked to the right, the system tracked the movement and calculated the yaw angle.(see Fig.4).

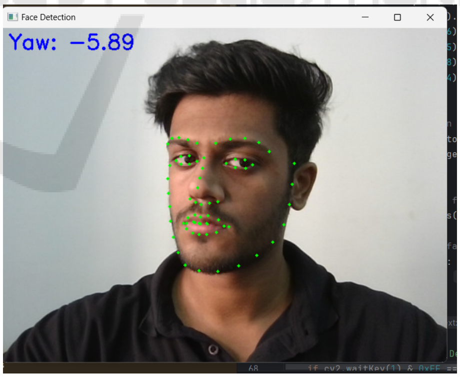

Figure 4: Yaw angle of face looking right.

4.3 Mobile Detection

The training process included dataset of 3250 images , number of epochs = 55, batch size = 16 and image size = 640 pixels for accurate identification of a mobile device.

After training final precision = 99%, recall = 92.7%, mAP50 = 97.6%, mAP50-95 = 77.4%

Table 2: Performance Metrics for YOLOv8 Training

Epoch	Precision	Recall	mAP50	mAP50-95
1	0.678	0.874	0.881	0.599
6	0.0303	0.707	0.0409	0.00887
11	0.00292	0.341	0.00268	0.00065
16	0.00486	0.415	0.00394	0.0015
21	0.837	0.876	0.913	0.592
26	0.734	0.944	0.855	0.582
31	0.809	0.931	0.903	0.648
36	0.899	0.902	0.953	0.662
41	0.951	0.949	0.974	0.743
46	0.973	0.870	0.960	0.743
51	0.981	0.927	0.973	0.740
55	0.990	0.927	0.976	0.774

4.4 Alert System

4.4.1 Face Looking Straight

The system effectively detected the face when looking straight at the camera(see Fig.5).

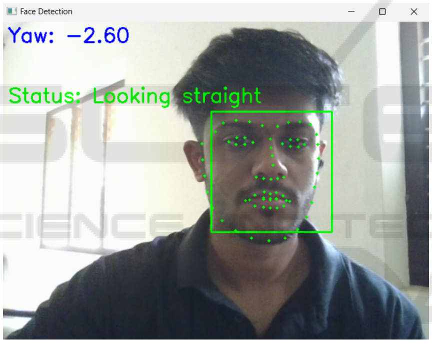

Figure 5: Output of face looking straight.

4.4.2 Face Looking Left

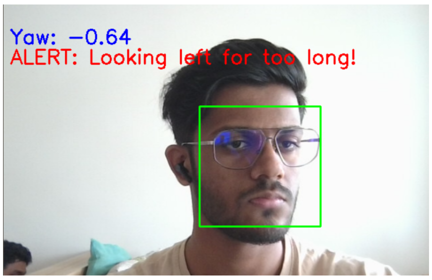

Figure 6: Output of face looking left.

When the user looks to the left, the yaw angle becomes negative. For instance, when the yaw angle exceeds the threshold of -1°, the system detects that the user is looking left. An alert is triggered if this condition persists for more than 3 seconds (see Fig.6).

4.4.3 Face Looking Right

Similarly, when the yaw angle exceeds 2°, indicating that the user is looking right, the system issues an alert after the defined threshold duration (see Fig.7)

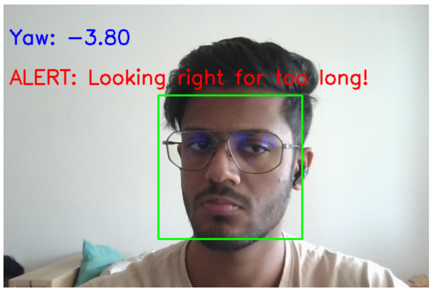

Figure 7: Output of face looking right.

4.4.4 Multiple Faces

In scenarios where multiple faces were present, the system triggered alerts(see Fig.8).

Figure 8: Output of face looking right.

4.4.5 Mobile Detection

In scenarios where use of smartphone was detected, the system triggered alerts (see Fig.9).

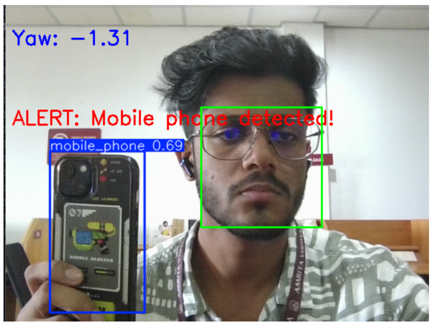

Figure 9: Smartphone detected

4.4.6 No Face Detected

In scenarios where no face was present, the system triggered alerts(see Fig.10).

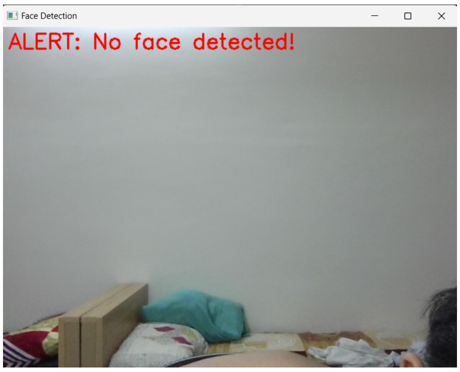

Figure 10: Output indicating that no face was detected.

4.5 Inference System Rules

Table 3: Rules and Decisions for Online Examination Proctoring

Number	Rules	Decision
Rule 1	If face of the examinee is missing from the frame at any point of time during the examination	Malpractice
Rule 2	Face shifting significantly from the initial position more than three times	Warning
Rule 3	Face shifting significantly from the initial position more than six times	Malpractice
Rule 4	If multiple faces are detected in the frame during examination	Malpractice
Rule 5	Sound above the threshold of mean-centered amplitude for more than 2 times	Warning
Rule 6	Sound above the threshold amplitude for more than 5 times	Malpractice
Rule 7	Opening any window other than the online examination window	Malpractice
Rule 8	Detection of smartphones	Malpractice

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5 CONCLUSION

The proposed AI-based proctoring system will ensure academic integrity in online examinations through facial recognition, mobile detection, audio monitoring, and tab tracking. The experimental results confirm the accuracy of detecting gaze deviations, unauthorized devices, and multiple faces. Thus, this provides a secure and reliable solution for remote assessments. Future improvements may include iris scanning to improve identity verification and algorithm refinement to work better under various conditions while reducing false positives and implementation of software defined radio (SDR) to detect mobile phones within a specified range of the exam attending system. This system provides a solid foundation for secure, fair, and transparent examinations on the Web.

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