Online Examination Proctoring for Quality Assurance in the Post COVID-19 Pandemic New Normal

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ABSTRACT

There has been a steady growth and usage of E-learning platforms over the past decade. However, with the Covid-19 pandemic, whereby lecturers and instructors in Institutions of learning could not have physical contact with the students, E-learning is witnessing astronomical growth and usage. Most of the available E-learning platforms in use have no proper solutions to academic examinations. Online Examination Proctoring System is an integrated system that uses live proctor(s) with an AI-enabled support. In the heat of the covid-19 pandemic, semester examinations conducted using online learning platforms by most learning institutions were marred with irregularity and academic fraud by the students. Some institutions gave out short essay questions in which the students copied from the internet, students were free to make calls and find answers from friends, and Instructors were not able to adequately create and author questions with graphics as would reflect their needs. At the same time, some implemented inefficient remote proctoring systems where a human invigilator keeps monitoring the students' activities. The lack of effective and efficient solutions to online examination proctoring by the e-learning platforms has led to cheating in the online examinations. With the covid-19 pandemic still very much with us and e-learning becoming the new normal, there is a need for researchers and developers to develop efficient and effective automated and online examination proctoring systems. This paper presents an Online Examination Proctoring System that detects and reports cheating in an online examinations. This ensures the integrity of the test which provides in overall, the desired quality assurance. The system was developed using Visual Studio Code installed on the system, and Anaconda environment was used to run the machine learning algorithms. The test results obtained from deploying the system showed significant improvement over the existing ones with 92% cheating detection rate.

1.0 Introduction

The origin of the term e-learning is not specific. Still, according to [1], it is most likely originated during the 1980s, within a similar time frame of another delivery mode, online learning. E-learning is a type of teaching and learning that is supported by electronic means, which comes from the broad diffusion of information through the networks and channels of telecommunication in education. E-Learning is defined by the American Society for Training and Development [2], as the use of the internet and digital technologies to create experiences of participating in education. The authors in [3] described online learning as access to learning experiences via the use of some technologies. E-learning have received attention over the decade because of the quest to globalize and make quality education and learning available to learners in disadvantaged environments and locations. These online courses aimed to attract knowledge from abroad and allow students on campus to pursue their education, leading to the localization of online classes and e-learning environments [4]. However, online proctoring, an integral part of e-learning, poses a more significant challenge in deploying an e-learning platform for the assessment of learners. Online proctoring involves the use of virtual tools for monitoring student activities during assessment activity. These tools have the potential for students to take an online examination at a remote location while ensuring the integrity and quality of the online examinations [5]. The utmost concerns of online proctor are the reliability, integrity and quality assurance. It includes the student's authentication and identity to secure and maintain the integrity of an examination and its administration [5]. Therefore an online examination proctoring system that ensures that assessments are reliable and possesses integrity by providing strict supervision that is more efficient, standardized, straightforward, and unbiased becomes pertinent [6].

E-Learning has been studied thoroughly in the literature from different points of view; attitudes and performances [7], learning management systems [8], and online courses and e-activities [9]. However, conducting an "e-assessment" or "e-examination" of students' performances under e-proctoring tools is still very limited [10, 11]; a highly desired tool for in and after the COVID-19 pandemic. Nevertheless, the COVID-19 pandemic has forced nearly all international students to either stop their education or depend entirely on online learning with no or very little and inefficient proctoring systems.

The authors in [10] asserted that one of the primary concerns for the educational system is the integrity of online assessments. The need to conduct the online examination using the appropriate tools and methods was emphasized by [12]. The need to ensure academic integrity has prompted institutions to adopt different e-proctoring technologies to monitor online exams. These technologies should validate students' identities and flags suspicious activities during the

exam to discourage cheating. The most disturbing problem identified in the existing Online Examination Systems is the lack of an efficient cheating detection module in the software to identify students indulging in malpractices. Hence, this paper aimed to fill the gap; develop a hybridized Online Examination Proctoring System that was tested and validated.

The remaining section of this paper is organized as follows; section 2 presents the literature review focusing on the overview and related works by researchers in online examination proctoring, section 3 discusses the methodology along with the system architecture. Section 4 detailed the results and discussion of the results and finally, conclusion, and future works are presented in section 5.

2.0 Related Works

Online examination proctoring is not new, as most institutions have been using the proctoring system for their tests. For instance, most competitive and adaptive examinations like GRE, GMAT, and CAT are purely online-proctor-based examinations [13]. Joint Admission and Matriculation Board (JAMB), University and Tertiary Institutions' Matriculation Examination (UTME) conducted yearly for prospective candidates seeking admission to higher institutions in Nigeria is invigilated using Live-Recorded proctoring. Some authors like [14, 15] asserted that the significant components in online proctoring are the webcam and locking. The web camera is for recording the student's video footings while taking the exam, which the invigilator can later view while the locking prevents students from opening other tabs on their web browsers during the examination. Features and types of proctoring systems were specified by [16]. The features as specified are; authentication, browsing tolerance, remote authoring and control, and report generation. The types of proctoring were listed as; live proctoring, recorded proctoring, and automated proctoring. The authors in [16, 17] specifies that the most advanced and current state-of-the-art proctoring systems are the automated types. Table 1.1 gives the definition and attributes of the various types of proctoring according to [16, 17].

Online proctoring systems are not without challenges hence, [18] explores various cybersecurity issues in the online proctoring system; the methods and techniques of multi-factor authentication and authorizations.

In [13], the author provided a comprehensive systematic review of existing works of literature in Artificial Intelligence (AI) based proctoring systems and non-AI-based proctoring systems. Through a routine search on Scopus, Web of science and ERIC repositories, 43 papers were listed from 2015-2023. The majority of these 43 papers were published by Springer, IEEE, Elsevier, Taylor and Francis Sage, Inderscience, and IGI Global. In addition, according to the authors, the documents selected for the review have a good number of citations.

The available state-of-the-art commercial proctoring system that highlighted their main features described them, and grouping based on the services offered was provided by [17]. The study also reported case studies on two examinations prosecuted with both automated and human proctoring methods. Finally, they summarized the experiences garnered from the two case studies and the outcomes of the state-of-the-art approaches.

Table 1.1: Types of Online Proctoring System

Types	Definition	Attributes
Live Proctoring	Require a person (the proctor) to be in a remote location to control the examinee's activities like a monitor in real-time, ensuring the test-taker's authentication and preventing any form of unfair actions. For example, if the examinee indulges in malpractice, the proctor can interrupt the exam.	Real time proctoring The system was introduced and tested in 2006: ● Human proctor is involved ● Suitable for theoretical exams and the exams which long last for 2-3 hours ● Human proctor can track eye movements, recognize the face of students can flag if students found cheating and malpractice ● Requires competence in use of technological ● enhancements
Recorded Proctoring	Do not make use of a human proctor to control examinee behaviours during the entire exam. The student behaviours are recorded during the examination. Teachers, professors, or people with proctoring functions must review the recorded video and check the presence of possible flags that signal doubt in an examinee's activities.	Involves video recording of candidate during examination and other logs details. ● Post proctoring involves tracking eye and face movements, object and face detection, log analysis etc. ● Human intervention is required but it very time consuming and costly
Automated Proctoring	Currently the most advanced programs available. Examinee behaviours are recorded during the test, and a computerized system then reviews the feedthrough advanced audio-video analysis functions to detect any abnormal or illicit activities	more advance version where humans do not proctor for the whole time, they just review ● system identifies fraud and cheating through various algorithms and technologies ● Since human proctors are not involved, It is cost effective ● Such types of systems are more complex to design.

Their conclusion asserted that organizations should make an effort to load photographs that can easily recognize students' faces and use an automated online proctoring program to support manual proctoring.

In [19], the authors proposed and developed an AI-based integrated system that can help prevent cheating in examinations. The developed method detected online exam malpractices such as using a mobile phone, sitting with a partner, switching tabs to look for answers from the web and leaving one seat during the examination. Moreover, the system will be able to report fraudulent activities, and proof of it stored on the examination portal.

Authors in [20] presented a multimedia analytics system that performs automatic online examination proctoring. The hardware

used includes; webcam, wear cam and a microphone. The hardware listed was used for monitoring the visual and acoustic environment of the testing location. They used six essential components that continuously estimate the key behaviour cues: user verification, text detection, voice detection, active window detection, gaze estimation and phone detection. The system was evaluated by the multimedia (audio and visual) data from 24 subjects performing various types of cheating while taking online exams. The experimental setup demonstrated 87% accuracy, robustness and efficiency.

Similarly, in [21] the authors proposed an enhancement of Remote Online Examination Model (ROEM) that can be used to authenticate the test taker remotely and detect cheating in an online test without regard to the online human proctor, fixed place, and fixed time. The model used a token algorithm and digital signature for the remote identification, fingerprint and keystrokes dynamics for authentication, and live video/audio surveillance for monitoring examinee during the online session. Thus, the model avoids the drawbacks of traditional examination, such as wasting time and wasting resources.

2.1 Drawback of the Existing Works

One of the drawback of existing online live proctoring systems that have only manual human proctor(s) who simultaneously watch-over a sizeable number of students is that the humans may be exhausted and fatigued and therefore lose concentration. In addition, for the live online proctoring system to be efficient, the ratio of human proctors to the number of students simultaneously taking the examination need to be high for an efficient and malpractice-free invigilation of the test. The system is not cost-effective, and human proctors sitting at home watching students writing examinations, most times, does not maintain absolute concentration. Recorded proctoring alone is very time-consuming and costly. The invigilator(s) has to undergo a strenuous review of the recorded files for each student involved in the examination to track malpractices. Finally, automated proctoring (fully AI-based) systems are cost-effective but are more complex to design [16].

2.2 Contribution of this work

The main contribution of this work is the development of a hybrid online examination proctoring system that combines live proctoring and automated AI features. Details of the design is as given in section 3.2.

3.0 Methodology

3.1 Data Gathering Techniques

The data gathered for this study was via detailed research and observations of proceedings during the 2019/2020 academic session's COVID-19 imposed online examination conducted in a private university in Nigeria. In addition, interactions with students of the said university on their experience in the online assessment generates valuable data and awareness on the problem of online proctoring. Papers and articles in online proctoring systems were also downloaded from databases, repositories and the latest implementations reviewed. Furthermore, documents have been gathered and examined from various educational platforms such as; Research Gate, Academia .edu, and Google Scholar. Finally, the researchers reviewed records from well renowned large-scale online proctoring systems such as Proctor-U, Examus, and SpeedExams.

3.2 The New Online Proctoring System Architecture

The proposed Online Examination Proctoring System (OE- Proctor) is an integrated online proctoring system that uses live proctor(s) with an AI- enabled support. The AI components help to control the integrity of the examination by tracking unique behavioural signals. The signals may prompt the live proctors' actions on the screen or prompt communication with the examinee via the monitor screen or webcam. Figure 3.1 depicts the system component diagram, while Figure 2 shows the architectural diagram of the OE-Proctor system. The components of the OE-Proctor are the users' authentication subsystem, online proctor(s), examinee and the surrounding space, AI support subsystem, and database. A brief explanation of each of the subsystems is as presented next.

i. ***Users' Authentication***

Authentication subsystem methods help ensure that the system users are truly the people they claim to be. For example, in a face-to-face examination, the students are identified with Identity cards and examination permits that specify the courses they are eligible to write. Users' authentication involves enrolment and verification.

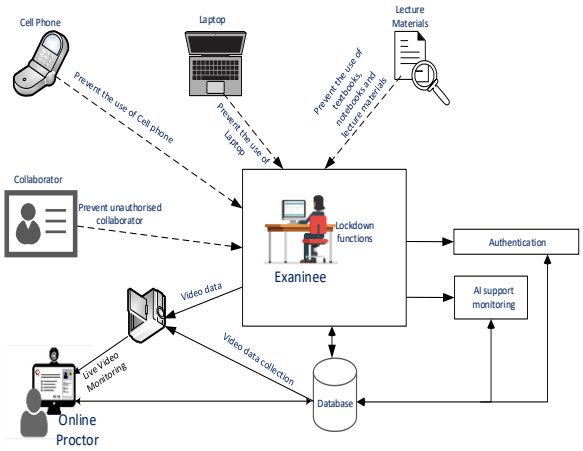

Figure 3.1: Proposed Online Examination Proctoring System (OE-Proctor)

Enrolment entails capturing the face of the candidates with face recognition readers and their other vital particulars during registration on the examination portal. Verification is the process of checking the details and identity of the students remotely in an online examination to ensure that it matches the particulars of those students who had earlier registered to take the test. Figure 3.3 shows the OE-Proctor authentication subsystem.

There are two kinds of authentication according to [22]; Static and Continuous authentication. Static authentication takes place at the beginning of the examination, allowed it to be valid until the end of the test when the user logs off.

Continuous authentication is the method of authentication that will continue after the start of the examination, and it will verify whether the current person is the same as the one who initiated the test or not.

The face recognition reader method ensures the automatic verification of the user writing the online examination since the human proctor cannot know the entire user participating in the test.

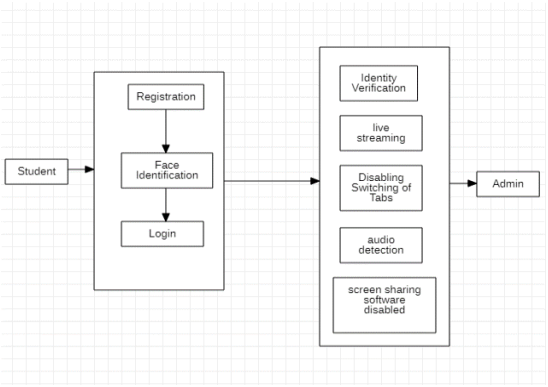

Figure 3.2: The block diagram of OE-Proctor system

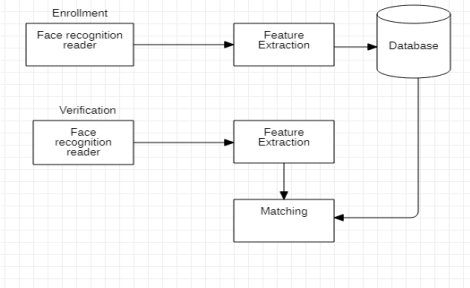

Figure 3.3: OE-Proctor authentication subsystem

Figure 3.4 shows the extracted region of the face. First, it consists of the enrolment module, in which case, the students face are captured and features extracted and stored in the database during registration. Then, the verification module compares the students sitting for the examination extracted features to match the already stored ones in the database.

Figure 3.4: Extracted region of the face

ii. ***Live Proctor(s) Subsystem:***

The proctor(s) role is to detect any cheating activities during the exam sessions. The live proctor(s) is also involved in the authentication process. He watches over the test takers via a live video streaming of the online examination procedure. The proctor(s) is expected to be proactive during the examination. He will play a significant role when there are technical issues during the examination sessions.

iii. Examinee and the Surrounding Space

The examiner is expected to take the examination in a well-lit room or space with a laptop or desktop computer with minimal hardware and software specifications required to take the test. These hardware features are the webcam and microphone. The test taker should not have close to him a cell phone, a lecture note or textbooks, iPad, and more importantly, should not have someone who will collaborate with him to cheat during the examination in the room. Section 4 give an explanation and procedures that were used to detect and handled most of these cheatings.

iv. Examinee and the surrounding space

The examinee is expected to take the examination in a well-lit room or space with a laptop or desktop computer with minimal hardware and software specifications required to take the test. There should be an uninterrupted internet connection with at least 512kbps speed. The software must include the latest version of Google Chrome, Mozilla Firefox, or other such browsers. In addition, the test taker should not have close to him a cell phone, a lecture note or textbooks, iPad, and more importantly, should not have someone who will collaborate with him to cheat during the examination in the room. Section 4 give an explanation and procedures that were used to detect and handled most of these cheatings..

v. AI Support System

The AI support monitoring system was be used in conjunction with the human proctor(s). The reason for using both live proctor(s) and the AI automated cheating detection method is to ensure efficiency. Moreover, the live proctor(s), from experience, will not guarantee absolute concentration during the test sessions. The AI support monitoring was used to support, track and report the cheating of types; mouth Open/Talking, mobile Phone detection, collaborator in the room (Person Counting), whispering/Background audio in the room, and face not visible/partially visible.

vi. The Database

The examinee data, information, the entire examination data, and test questions and recorded video are stored in the database. The database server is maintained for this purpose.

3.3 System Flowchart and Algorithms

The system Flowcharts of the OE-Proctor system is as depicted in Figure 3.5. It consists of Authentication (using face recognition) and the examination monitoring proper while the face recognition algorithms is presented in algorithm-1.

3.4 Experimental Setup

This section discusses the experimental setup put in place to evaluate OE-Proctor. The focus of the experimental design was to answer the following questions: 1) How well was the OE-Proctor able to detect cheating of the various kind being investigated?. 2) What was the cheating detection rate of the various cheating types being investigated? 3) What is the efficiency of the OE-Proctor? The experiments involved 25 students grouped into five batches seated at different halls in the faculty of Science in a private university in Nigeria. Among the students, 20 students were to take the status of cheating of various kinds during the examination sessions. The other set consisted of five students, was to take the position of non-cheating. The experiment consisted of 5 sessions, each lasting 10 minutes and spread across five days. The size of data equals 25 samples in this experiment. Each examination session lasted for an average of about 10 minutes. The questions set are ICT questions from the random generator.

The researcher instructed the students in the cheating category to indulge in the various types of cheating to be captured, as shown in Table 4.1.

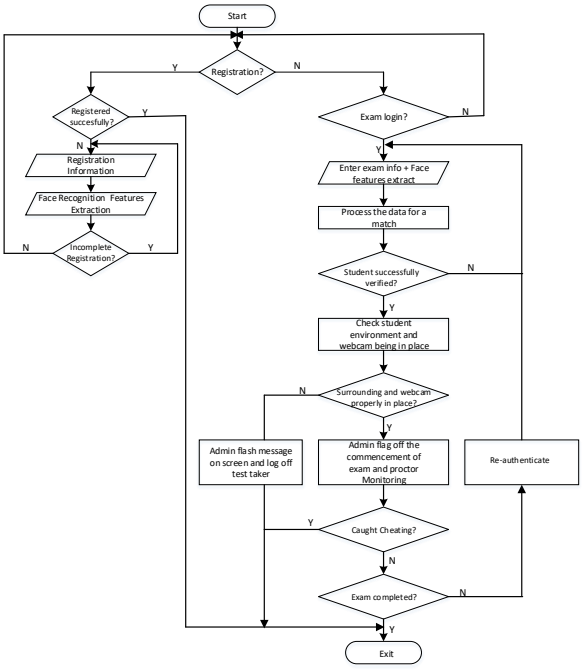

Figure 3.5: The OE-Proctor system flowchart

Algorithm-1: User verification face detection algorithm
Data: A new frame I_t, h_f
Result: v_p, v_n
Initialization: $v = 0$, $c_0 = c_1 = 0$;
Viola-Jones face detector → $v_n(t)$;
switch $v_n(t)$ do
case 0
if $c_0 > \tau_0$ then
$p_t = v_p(t) = c_0 = 0$; % warning is sent
else
c_0 ++;
$v_p(t) = v_p(t - 1)$;
$p_t = F(v_p(t), v, \bar{t}, \bar{p})$;
case 1
$c_0 = c_1 = 0$;
if $v = 1$ then
Compute h_t, $p_b = h_t^T h_b$
if $p_b > \tau_v$ & $p_{t-1} > \tau_v$ then
$p_t = F(v_p(t), v, \bar{t}, \bar{p})$;
else
$v = 0$;
if $v = 0$ then
$c_t = x_t \otimes h_f$, $v_p(t) = PSR(c_t)$;
$p_t = F(v_p(t), v, \bar{t}, \bar{p})$;
if $p_t > \tau_v$ then
$v = 1$, $\bar{t} = t$, $\bar{p} = p_t$;
case > 1
if $c_1 > \tau_0$ then
$p_t = v_p(t) = c_1 = 0$; % warning is sent
else
c_1 ++;
$v_p(t) = v_p(t - 1)$;
$p_t = F(v_p(t), v, \bar{t}, \bar{p})$;

3.5 Procedure and Steps Involved in Test-taking

The procedures and steps involved in verifying examinee and monitoring during the examination is being discussed in this section.

i. Procedure examinee verification before the examination

Step 1: Firstly, the examinee must fill in all the required fields, including the name, matric number, gender, and exam particulars.

Step 2: Next comes the authentication/authorization page, where the examinee lets the OE-Proctor system take control by allowing for screen sharing, video, and audio.

Step 3: The examinee has to show ID proof; the human proctor validates this. Afterwards, the facial recognition feature was extracted and validated. The human proctors are available round-the-clock, verifying every applicant's photo ID against the previously shared registration detail on the server to attest to their legitimacy.

ii. Procedure supervision/monitoring during the examination

Step 1: The OE-Proctor ensures that only those who have duly completed the online registration for a subject takes the examination

Step 2: The OE-Proctor software analyses the examinee's behavior, examinee's screen and examinee's environment. The modalities employed are as follows:

a. Monitoring the examinee behaviour:

With the help of AI, an online invigilator monitors every action and activity of the test-taker remotely. Conditions such as an applicant's face not visible or partially visible, presence of another person in the room, constantly distracted movements, presence of an unauthorized device and whispering in the room. The OE-Proctor flagged off these activities during the exam proctoring process. However, the human proctor has the final decision to count the flagged activity as cheating.

b. Monitoring the examinee's screen and system

The lockdown browser feature is a customized browser setting that prevents any form of digital/ on-screen cheating during an online exam.

The lockdown browser runs full screen on the system; hence, the student cannot move out of the window or access any unauthorized application. The lockdown browser encompasses the following:

- No opening of new browser tabs
- Blocking copying/pasting content
- OE-Proctor closes all running browser tabs

c. Monitoring the examinee's environment

Monitoring the environment take into account third-party collaborator who often collaborates with test-takers and help them cheat. These helpers are stationed away from the student and the webcam, preferably behind the system. The 360-degree video capturing webcam ensured that this form of cheatings were curtailed.

Both these cameras allow the live proctor or the AI-proctoring software to view areas beyond the laptop/webcam feed coverage, providing an extra layer of security during virtual exams..

OE-Proctor ensured audio filtering by capturing background noise in the examinee's environment using the microphone.

iii. Procedure evaluation/report generation

Step 1: When the time is up, the online-proctored exam is evaluated, and the results are automatically submitted.

4.0 Implementation and Experimental Results

This section of the work discusses the hardware and software tools. In addition, the implementation procedure for each of the cheating detection procedures is explained.

4.1 Hardware and Software Tools

(i) Hardware Tools

Firstly, Webcam and microphone compatible computer and an uninterrupted internet connection. The examinee requires a suitable device (Desktop pc/Laptop) with a functional webcam and microphone. In addition, the latest version of Google Chrome, Mozilla Firefox, or other such browsers, an Internet connection with at least 512kbps speed.

(ii) Software Tools

OE-Proctor was implemented using Visual Studio Code installed on the system. The Anaconda environment was also used to run the machine learning algorithms modules for the proposed system; it is a free and open-source distribution of the Python and R-programming languages for large-scale data processing, predictive analytics, and scientific computing. The AI capabilities of the Hybrid Proctoring system were created in python using a webcam and microphone.

The library and modules for the automated cheating detection were implemented using these libraries:
i. *Dlib facial keypoint* detector and *OpenCV* was deployed in the implemented gaze estimation.

ii. Pre-trained weights of YOLOv3 in TensorFlow2 trained on the COCO dataset[23]were used to detect people and mobile phones in the webcam feed to implement the person counting and mobile phone detection. Then the classes of objects detected are checked and appropriate action is taken if more than one person is detected or a mobile phone is detected.

iii. Both **capabilities** are combined using multi-threading. A single thread was created for eye-tracking and mouth detection based on dlib, while another thread was created for people counting and mobile detection using YOLOv3. Firstly, the entire necessary library imported, and then the dlib and YOLO models are loaded.
iv. The speech from the microphone will be recorded, converted to text, and will be compared to the text of the question paper to report the number of common words spoken by the test-taker.

4.2 Results and Discussions

This section discusses the results obtained from the OE-Proctor system. OE-Proctor was used for each of the five examination sessions stated in section 3.2, and the system raised real-time cheating flags. In addition, video from the camera mounted for the experiments was collected and labelled accordingly for review. The labelled video and audio files were reviewed for the various cheating types as contained in Table 4.1. Table 4.1 shows the cheating instances recorded with flags raised for the examinee that perpetrated them.

4.3 Evaluating the Online Examination Proctoring System (OE-Proctor)

The system will be evaluated by presenting the results obtained from the components parts of the system; the results obtained by the human proctor and the results recorded by the OE-Proctor software.

The cheat type frequency and its percentages in the entire examination sessions is shown in Figure 4.1.

Table 4.1: Cheating instance behavior reported

S/N0	Stud ID	Location/ Room No	Nature of Cheating indulged in by students					
			Authenticatio	Make Face not Visible/Partiallv	Mouth Open/Talking	Mobile Phone Detection	Collaborator in the room (Person Countinel	Whispering/Backgroudn audio I n the room
1	XXX	Lab1		✓		✓	✓	
2	XXX	Lab2		✓	✓	✓		
3	XXX	CBT				✓		✓
4	XXX	CBT			✓		✓	
5	XXX	Lab1		✓		✓		✓
6	XXX	Lab2				✓	✓	✓
7	XXX	CBT		✓		✓		
8	XXX	A10					✓	
9	XXX	A10			✓	✓		✓
10	XXX	B15	✓					
11	XXX	B15		✓		✓	✓	✓
12	XXX	CBT					✓	✓
13	XXX	CBT		✓		✓	✓	✓
14	XXX	CBT			✓			
15	XXX	CBT		✓		✓	✓	✓
16	XXX	CBT						✓
17	XXX	CBT		✓	✓		✓	
18	XXX	CBT	✓					
19	XXX	Lab1		✓		✓		
20	XXX	Lab2			✓	✓	✓	✓
21	XXX	A10						
22	XXX	B15						
23	XXX	A10						
24	XXX	B15						
25	XXX	A5						

i. Performance of Human Proctors

Human proctors monitor the examinee visually via webcams. It equally records the examinees' cheating behaviours and types to access its performance and contrast with the result from the OE-Proctor software. Five proctors are involved in the invigilation, review the video recording, and manually record the cheating instances. Table 3 shows the result obtained from recording the cheating instances by the five proctors after the offline review of the recorded video.

***ii. Evaluating* OE-Proctor**

Two parameters that are very important in analysing the cheating instances are the True Detection Rate (TDR) and the False Alarm Rate (FAR). The definition of TDR and FAR parameters for a particular subject session, i, are as given in equations 1 and 2. Table 4.3 shows the values of cheat detection and false alarm instance flagged time recorded across the experiment sessions by the OE-Proctor. The cumulative TDR_T and cumulative FAR_T of the cheat instances for the entire five sessions of the **OE-Proctor** is calculated as:

$$\mathbf{TDR_i} = \frac{\sum_i True\ ins\tan ce\ \det ections\ of\ subject\ i}{\sum_i No\ of\ cheat\ ins\tan ces\ of\ subject\ i} \quad \text{---Eq.1}$$

Table 4.2: Cheating Instances Recorded by the Human Proctors

Cheating Types **No of detected Instances**	Make Face not Visible/Partially visible	Mouth Open/Talking	Mobile Phone Detection	Collaborator in the room (Person Counting)	Whispering Background audio in the room	Total no recorded per session
Sesion 1	3	2	4	2	2	13
Sesion 2	1	1	3	2	2	9
Sesion 3	3	1	3	4	4	15
Sesion 4	2	2	2	2	2	10
Sesion 5	Nil	Nil	Nil	Nil	Nil	Nil
Total	9	6	12	10	10	**47**

Table 4.3: Cheating Instances Flagged by the OE-Proctor

Cheating Types **No of detected Instances**	Make Face not Visible/Partially visible	Mouth Open/Talking	Mobile Phone Detection	Collaborator in the room (Person Counting)	Whispering Background audio in the room	Total no recorded per session
Sesion 1	3	2	4	2	2	13
Sesion 2	1	1	3	2	2	9
Sesion 3	3	1	3	4	4	15
Sesion 4	2	3	2	2	2	10
Sesion 5	1	1	0	0	2	4
Total	10	8	12	10	12	**51**

Table 4.4**: Cheat Types Flagged by OE-Proctor in the Entire Examination Sessions Together with False Flag Recorded**

Cheating Types	Make Face not Visible/Partially visible	Mouth Open/Talking	Mobile Phone Detection	Collaborator in the room (Person Counting)	Whispering / Backgroud audio in the room
No of detected Occurrences Recorded	11	7	12	10	12
No of False flag raised Recorded	2	1	Nil	Nil	2

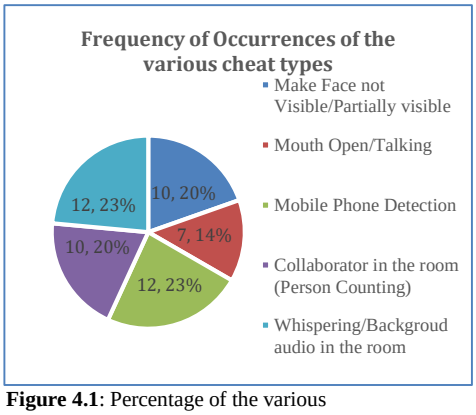

Figure 4.1: Percentage of the various cheating types recorded by **OE-Proctor**

Table 4.5: The values of cheat detection and false alarm flagged time across the experiment sessions

Cheating type	**Detection time (s)**	**False alarm time (s)**
Make Face not Visible/Partially visible	298	64
Mouth Open/Talking	254	33
Mobile Phone Detection	1830	Nil
Collaborator in the room (Person Counting)	1085	Nil
Whispering/Backgroud audio in the room	815	54

$$\textbf{.FAR}_{\textbf{i}} = \frac{\sum_i \textit{False alarms of subject } i}{\sum_i \textit{No of cheat} - \textit{free minutes of subject } i} \text{ ------Eq.2}$$

$$TDR_T = \frac{\textit{Total cheating instances recorded across sessions by proctor(s)}}{\textit{Total cheating instances flagged by OE-Proctor}}$$

$$47 / 51 \approx 0.92$$

$$FAR_T = \frac{\textit{Total false alarm raised across the sessions}}{\textit{No of free} - \textit{cheat minutes across the sessions}}$$

$$5 / 71.4 = 0.07$$

4.4 Discussion of Results

As earlier stated in section 2.2, the main contribution of this work is to have a hybrid online examination proctoring system that combines live proctoring and automated AI features. The OE-Proctor performs creditably well in

detecting the cheating types being investigated based on the performance evaluation carried out on the online exam proctoring system. The results obtained from the human proctor(s) and that of the OE-Proctor agree largely. From table 4.5, the OE-proctor recorded a 92% success rate in detecting and flagging the various cheating types.

From the results obtained in Tables 4.4 and 4.5, the mobile phone detection and person counting witnessed a 100% detection and flagged accordingly. In addition, the other cheating types the experiment was designed to track were detected by the OE-Proctor at an average success rate of 84%.

The system efficiency in detecting the cheating types was outstanding. However, the results achieved can be improved upon by the researcher in future works.

5.0 Conclusion and Future Works

5.1 Conclusion

This paper addressed the problem of cheating in online examinations by developing an online proctoring system. The developed Hybrid online proctoring system aimed at maintaining academic integrity, especially in this era of COVID-19 created new normal. The design combined the integrated approach of live and AI-enhanced proctoring. The integrated approach ensures the system's efficiency; human proctors monitor the examination together with AI support.

The AI subsystem consists of the user verification and monitoring of the examinee for the five cheating behaviours of making a face not visible/partially visible, mouth open/talking, mobile phone detection, collaborator in the room (person counting), and whispering and background audio in the room. The implementation was done using the visual Studio code installed on the system, and the Anaconda environment was used to run the machine learning algorithms modules.

The Online examination system was tested and evaluated with 25 examinees at a private university in Nigeria and perform creditably well in detecting the earlier mentioned cheating behaviours. In addition, the system was able to track instances of cheating behaviours with an efficiency capability of 92**%.**

5.2 Future Works

The work can be enhanced by implementation over the web with cloud based storage. This further improvement in the research will ensure that the bulky video data generated from the system will be stored and managed on the cloud.

Furthermore, the future area that needs attention and improvement is the area of security and privacy of the examinee. The recording of the examinee and the surrounding environment by the mounted cameras posed a security challenge. Protecting the recorded data is very important, especially in this era of kidnapping and banditry, as the video might get to the hand of an intruder.

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