ARTIFICIAL LEARNING-BASED PROCTORING SOLUTION FOR REMOTE ONLINE ASSESSMENTS: "vProctor"

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ABSTRACT:

Technological developments have paved the way for courses, trainings and assessments to be made online remotely in education and employment. In the meantime, over the years, the demand for online distance learning has increased rapidly. Eventually, it has been seen that this is a necessity and it has become widespread during the COVID-19 pandemic period. As can be seen in the example of massive online open courses, although remote learning is carried out online, perhaps the most important problem is how to evaluate the relevant courses safely and reliably. Thus, remote online proctoring is becoming an increasingly popular and needed issue. In this study, the issue of conducting the examination remotely online via internet-connected video and audio communication will be evaluated. Furthermore, the solution called vProctor was developed to contribute to the elimination of deficiencies in remote online proctoring using artificial learning. Overall, it has been observed that the proposed solution is managed to determine inappropriate behaviors like cheating in the online assessments.

1. INTRODUCTION

With the COVID-19 pandemic, lessons, courses and trainings have started to be made by providing access from anywhere in the world as long as learners have an internet connection, instead of being physically in the enclosed rooms as in the past. Although many successful software has been developed in this regard, the severely lacking aspect of the system is to conduct secure and reliable online exams remotely. It is because, in any exam, there is a possibility of cheating, and thus, its detection and prevention are important issues.

Online education and online examinations are two sides of the same coin, and bridging the gap between these is very important. Various researches and developments are being made to develop proctoring technologies to ensure that the level of online examinations is at par with offline examinations in all aspects. So much so that, educational institutions and corporate organizations across the world had gradually begun the process of adopting online proctoring software over the past decade to conduct remote examinations in a fair manner and ensuring that the candidates gave the exam in a known environment. [Nigam et al., 2021] Hussein et al. classified online proctoring systems into 3 groups as displayed in Figure 1.

Presently, human proctoring is the most common approach of evaluation, by either requiring the test taker to visit an examination center and take an exam under in-person proctoring, or by monitoring them visually and acoustically during exams via a webcam from a remote location. Nevertheless, they still rely on a person surveillance the exam-taking. Online human monitoring is one common approach for proctoring online exams. The proctors are trained to watch and listen for any unusual behaviors of the test taker, such as unusual eye movements, or removing oneself from the field of view. They can alert the test taker or even stop the test. The main downsides of such method are labor intensive with the need for invigilators and costly especially if you apply this method at a large scale. More economically viable solutions are sought. [Atoum et al., 2017]

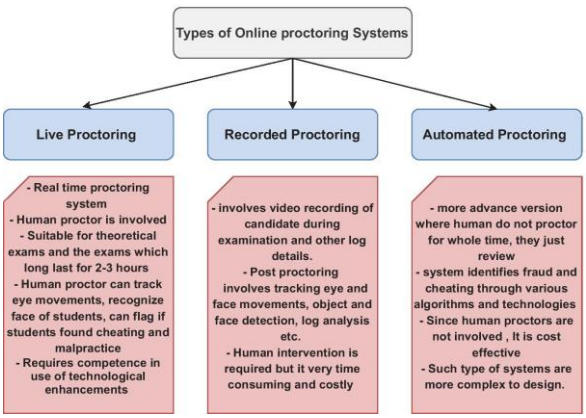

Figure 1. Types of online proctoring systems.

Furthermore, some studies have highlighted the problem of onsite human invigilators. Apampa et al. for instance, have highlighted a problem of similarity between candidates and the difficulty that an invigilator could face in differentiating between lookalikes, family members or twins. Moreover, an invigilator could cooperate with the fraudulent student to allow cheating actions; or the problem of the juxtaposition of students during online examinations [Gilbert et al., 2009]. On the other hand, many limitations can be identified with in-person remote proctoring system including: the time and storage required to review the recorded video/audio, the possibility of academic dishonesty, human emotions, or lack of concentration of proctor during the exam time. That is why many institutions around the world no longer rely on such human proctored-only unsecure assessments which have the potential for incidents of academic dishonesty. [Ketab, 2015]

Secure testing has traditionally necessitated an onsite proctor to attend to the concerns, such as proctoring test content, ensuring authenticity of test-taker identity, and maintaining validity and equivalent interpretation of scores and subsequent decisions. Nevertheless, recently, the practice of using remote online proctors has emerged on the high-stakes testing landscape. In remote proctoring, test content is delivered to test-takers using their own computers, anytime/anywhere, and a video recording is captured via web camera without live supervision (e.g., record and review later). As an added level of security, live proctors in a remote location may interact with the examinee and observe the scheduled testing session in real time via video technology. [Weiner, Hurtz, 2017]

In this study, the solution called vProctor was developed to overcome the essential problems in remote online assessments. vProctor performs virtual online exam invigilation process through visual and audio observations to detect any suspicious actions during the assessment that may enable the student to cheat. vProctor accomplish this process by providing real-time remote monitoring of an examinee or video recording of an examinee's behavior during the test period.

2. THE PROPOSED SYSTEM FRAMEWORK

The proposed solution uses a combination of hardware and software components to provide secure online assessment conditions, as shown in Figure 2.
First, the system includes two basic components: Desktop/Laptop Software and Mobile Application. Cross-platform desktop client application mainly performs facial recognition and does not allow the examinee to run any other software than the exam software. In order to ensure the safety of the exam environment, it will be requested to display the environment of the examinee taking the exam. In addition to this, it is also requested to take a photo of the computer on which the exam is performed via a smart phone in order to prevent any cheating. Mobile app is responsible for taking an ID photo and taking 360 degree photos of the test taker's surrounding. Mobile devices such as smartphones integrated with the mobile application are utilized to provide a highly secure exam environment. Development tools such as Haxe and Electron were used to make the vProctor solution cross platform. Thus, the secure exam application will be able to run on different operating systems. The desktop component of vProctor can be integrated into any exam system through technologies such as IFrame, API, XML, JSON. In similar way, development was made with React Native, which provides cross-platform support on the mobile side.

To take 360 degree photos of the exam environment, examinee has to take photos until s/he finds a total of 360 degrees in the form of certain angles. This is executed by accessing the phone sensors with the react-native-sensors library. Thanks to the gyroscope sensor of the smartphone, the angular ratios of the phone in the three vertical axes are compared, and thus the direction of rotation and speed are calculated.

Microservice architecture was used on the server side. The services developed under the microservice architecture are the following:

- Authentication Service
- Exam Service
- Image Processing and Voice Classification Service
- Assessment Service
- Reporting Service
- Notification Service
- Customer Service

EventBus approach over ZeroMQ technology was used to synchronize data exchanges between services and to transmit events from one point to another. Thus, vProctor and services in the microservice infrastructure could communicated through HTTP with the Publish-Subscribe method by means of EventBus.

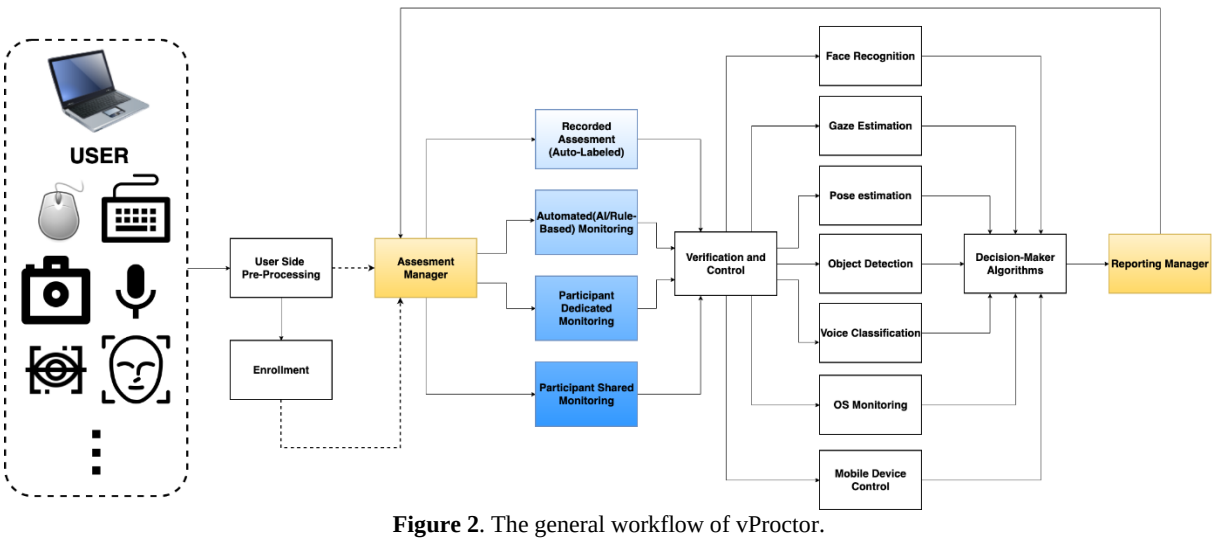

Figure 2. The general workflow of vProctor.

vProctor has five computer-vision capabilities:

- face detection and recognition during the exam period
- gaze tracking and gaze estimation to capture the test taker's focus
- body tracking and posture estimation to capture the test taker's focus
- object recognition to identify forbidden objects in the exam environment
- person recognition

Addition to image-based capabilities, it has also audio-based feature, which is the perception of human voices in the exam

environment and sound classification. In this way, whether the ambient sounds produced during the exam belong to a human or not can be analyzed with sound classification algorithms through pyAudio Analysis and Tensorflow libraries in order to designate the voice of another person other than the test taker.

The libraries used for artificial learning developments within the scope of the study are listed below:

- FaceNet neural network with CUDA toolkit and cuDNN was used for face recognition process. The training data set was LFW data set.
- The GazeCapture library was used for eye tracking.
- The OpenPose library with CUDA toolkit and cuDNN was used to detect body parts. In this approach BODY_25 model was used to detect non-parametric Part Affinity Fields (PAF).
- Mask R-CNN library was used for object identification. In order to obtain pre-trained weights, Common Object in Context (COCO) data set was used.
- VADNet library was used trough CNN and RNN architcetures for human voice detection. The VADNet model is trained with TensorFlow. It feeds the received signal as input to the 3-layer CNN. The result of this filtering operation is then processed by the 2-layer RNN. Finally, SoftMax is applied to output a decimal number between 0 and 1, indicating whether it is sound or noise.

Addition to all these, other capabilities of the proposed system are computer screen tracking, keyboard/mouse tracking and operating system monitoring in order to lock the computer or web browser when necessary. vProctor provides easily access computer peripherals such as screen, microphone, camera, mouse and keyboard to ensure no other computer resources are being used to cheat and to maintain secure testing environment.
The following can be given as examples of cheating behaviors of a person who is considered within the scope of the study:

- another person taking the exam,
- focusing on off-screen locations from the computer on which the examinee took the exam,
- cheating with another person's voice commands,
- cheating via headphones,
- transferring hand-arm movements to test taker's surroundings,
- text, picture placed in the exam environment before the exam.

There always exists a possibility that concealed cheating activities might happen outside the fields of view of a camera, for instance a partner who is outside the camera view, but can see the test questions (e.g., on a second monitor), could supply answers to the test taker using silent signals, or writing on a piece of paper which is visible to the test taker [Rosen, Carr, 2013]. To remedy this, vProctor incorporates a range of different facilities to detect suspicious human behaviors.

The brain of the proposed system is an algorithm for AI decision making that tries to catch suspicious situations for hybrid use of different technologies such as eye and head movements, sound and computer processing and inputs. Low-level features from 8 various capabilities of vProctor are evaluated to acquire high-level behavior cues and this leads to a joint decision to provide the detection of cheating behavior. If such behavior is detected, vProctor may suspend the test or not interfere with the examination and generate a report for later review by the testing agency.

Some of the other highlights of the vProctor solution include:

- The exam environment conditions (sound, light, etc.) determined by the exam providers before the exam are checked and the exam is started when these conditions are met.
- Guiding the test taker by calculating the correct positions of the face from the test taker's facial images during the recognition of the user's face
- Verifying the examinee's authenticity non-intrusively and continuously throughout their session
- After obtaining panoramic photos of the exam environment with a smart phone, the control process is carried out with deep learning algorithms without a human supervisor.
- Reporting inappropriate or suspicious movements by controlling the examinee's body movements with pose estimation
- By distinguishing the sounds in the background noise, reporting in case of detecting a human voice other than the test taker
- Identifying and reporting objects and texts that are not allowed to be found around with deep learning
- Maximizing exam performance and security by considering the relationships between parametric business rules before and during the exam
- For situations where internet connection may be problematic or there is no need for real-time monitoring, there is the option to perform the exam environment or a predetermined motion control only at the beginning of the exam and after the exam, or at a random moment.

Another goal of the study is real-time reporting of examinee behaviors. To achieve this, each candidate's image must be processed simultaneously. For this case, in addition to a strong hardware infrastructure, an asynchronous architecture was designed within the scope of the study. Thus, developments were made with minimum delay. The most important part of the architecture is the use of WebRTC technology to transfer examinee images to the container with the help of FFMPEG technology. Thus, asynchronous processing of streams in all containers is ensured for each examinee. It was implemented that the frames are transmitted instantaneously with minimum delay without being stored or corrupted. Thereafter, based on these results, necessary reporting processes were carried out.

Even with all the features of vProctor, it is possible that vProctor might not achieve flawless performance. There will be false positives and false negatives as well as true positives. For authors, as long as vProctor detect the majority of suspicious behaviors with reasonably small number of false positives and false negatives, its benefits outweigh the false positives and false negatives. The rest of the performance is considered to be related to the trade-off between accuracy and cost. Commercially, there are also many companies that produce solutions for the problem of online assessment in the market, such as: Examity, OnVUE, and ExamShield. Table 1 shows a comparison of commercial products and vProctor solution over some features.

Technical Feature/ Product	Examity	OnVUE	ExamShield	vProctor
Cross Platform	No	No	No	Yes
Human Proctor	Yes (optional)	Yes (compulsory)	Yes (compulsory)	Yes (optional)
Artificial Intelligence	Yes (optional)	Yes	No	Yes
Mobile Application	Yes (before exam)	Yes (before exam)	No	Yes
Screen Sharing	Yes	No	Yes (compulsory)	Yes
Additional exam-related application installation requirement	Yes	Yes	Yes	Yes
External Application Integration	No	No	No	Yes

Table 1. Comparison of similar products on distance exam.

3. CONCLUSION AND OUTLOOK

In this study, the solution named vProctor was developed to overcome the essential problems in remote online exams. vProctor carries out, virtual robust online exam invigilation process to detect inappropriate human behaviors such as a wide variety of cheating behaviors (e.g. using the Internet and computer resources or getting unauthorized help from the surrounding environment to answer questions). vProctor also allows the examinee to take an online exam wherever and whenever they desire. This allow for greater flexibility in test operations.

The proposed system, vProctor was found convenient and easy-to-use by test-takers. Although higher cheating instances was expected in online exams than in-person proctored conditions, exam experts consider vProctor as a system that reduces cheating in remote exams. In addition, vProctor was rated by exam experts as nearly reliable and equivalent to the traditional proctoring environment at a certified test center. Additionally, vProctor can monitors multiple students in online exams at a time.

Despite their drawbacks, it is expected that the digital exams and assessments, from the examination evaluations of schools and universities to the personnel recruitment processes of human resources, would be made with artificial learning-based monitoring systems in the near future. Moreover, in the near future, it is considered that the quality of a person's online certificate will be evaluated directly depends on the quality of the testing process that the person goes through to obtain it. There is a growing trend in the employment context in terms of employee selection testing which realizes exams and obtain their scores on completely unproctored internet tests.

REFERENCES

Apampa, K.M., Wills, G.B., & Argles, D. (2010). User Security Issues in Summative E-Assessment Security. Internet Technology. International Journal of Digital Society (IJDS), Vol 1 (2).

Atoum, Y., Chen, L., Liu, A., Hsu, S., Liu, X., 2017: Automated Online Exam Proctoring. *IEEE Transactions on Multimedia* 19 (17), 1609-1624, doi.org/10.1109/TMM.2017.2656064.

D'Souza, K.A., Siegfeldt, D.V., 2017: A Conceptual Framework for Detecting Cheating in Online and Take-Home Exams. *Decision Sciences Journal of Innovative Education* 15 (4), 370-391, doi.org/10.1111/dsji.12140.

Gilbert, L, Gale, V, Warburton, B & Wills, G. (2009). Report on Summative E-Assessment Quality (REAQ), JISC, London, viewed 26 Sep 2021, <https://www.webarchive.org.uk/wayback/archive/20140614094217/http://www.jisc.ac.uk/whatwedo/projects/reaq.aspx>.

Hussein, M. J., Yusuf, J., Deb, A. S., Fong, L., Naidu, S., 2020: An Evaluation of Online Proctoring Tools. *Open Praxis* 12(4), 509, doi.org/10.5944/openpraxis.12.4.1113.

Ketab, S., 2015: E-invigilation of e-assessments. Proceedings of INTED2015 Conference. March 2015, Madrid, Spain, ISBN: 978-84-606-5763-7.

Nigam, A., Pasricha, R., Singh, T., Churi, P., 2021: A Systematic Review on AI-based Proctoring Systems: Past, Present and Future. *Education and Information Technologies* 26, 6421–6445, doi.org/10.1007/s10639-021-10597-x.

Rosen, W.A., Carr, M.E., 2013: An autonomous articulating desktop robot for proctoring remote online examinations. IEEE Frontiers in Education Conference (FIE), 1935-1939, doi: 10.1109/FIE.2013.6685172.

Weiner, J.A., Hurtz, G., 2017: A Comparative Study of Online Remote Proctored Versus Onsite Proctored High-stakes Exams. *Journal of Applied Testing Technology* 18(1), 13-20.