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REVIEW

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AI-Driven Learning Management Systems: Modern Developments, Challenges and Future Trends during the Age of ChatGPT

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ABSTRACT

COVID-19 pandemic restrictions limited all social activities to curtail the spread of the virus. The foremost and most prime sector among those affected were schools, colleges, and universities. The education system of entire nations had shifted to online education during this time. Many shortcomings of Learning Management Systems (LMSs) were detected to support education in an online mode that spawned the research in Artificial Intelligence (AI) based tools that are being developed by the research community to improve the effectiveness of LMSs. This paper presents a detailed survey of the different enhancements to LMSs, which are led by key advances in the area of AI to enhance the real-time and non-real-time user experience. The AI-based enhancements proposed to the LMSs start from the Application layer and Presentation layer in the form of flipped classroom models for the efficient learning environment and appropriately designed UI/UX for efficient utilization of LMS utilities and resources, including AI-based chatbots. Session layer enhancements are also required, such as AI-based online proctoring and user authentication using Biometrics. These extend to the Transport layer to support real-time and rate adaptive encrypted video transmission for user security/privacy and satisfactory working of AI-algorithms. It also needs the support of the Networking layer for IP-based geolocation features, the Virtual Private Network (VPN) feature, and the support of Software-Defined Networks (SDN) for optimum Quality of Service (QoS). Finally, in addition to these, non-real-time user experience is enhanced by other AI-based enhancements such as Plagiarism detection algorithms and Data Analytics.

KEYWORDS

Learning management systems; chatbots; ChatGPT; online education; Internet of Things (IoT); artificial intelligence (AI); convolutional neural networks; natural language processing

1 Introduction

During the years 2019–2020, the problem of COVID-19 suddenly engulfed all social activities, particularly education, to contain the pandemic disease [1]. The foremost and most prime sectors among those affected are schools, colleges, and universities. The education system of entire nations had shifted to online education during this time. The Learning Management Systems (LMSs) in universities, which previously functioned in supporting roles only, suddenly found themselves thrust in the forefront [1–3]. For instance, in previous years, LMSs had limited features and functions. They lacked analytical abilities; the User Interface was far from being user-friendly, and they could not host safe exams. This precipitated a race to enhance and improve LMSs in universities to entirely support online education when physical classes were impossible. Consequently, today, LMSs are synonymous with education, offering end-to-end solutions replete with unique features and functionalities. The global LMS market is projected to grow from USD 13.38 billion in 2021 to USD 44.49 billion in 2028 [2]. To date, online exams software that can combat the menace of cheating has only been effectively developed for the Multiple Choice Questions (MCQ) system of exams [4] but not for other varied natures of exams, e.g., subjective, theoretical, numerical-based with varied guidelines such as open/closed book and internet permissions. Due to these reasons, both schools'/colleges'/universities' academics and students'/parents' [5] are dissatisfied with the online classes and online examination systems. This dissatisfaction primarily results from the (i) Lack of proper teacher-student interaction during online classes due to various internet and electricity disruptions; (ii) Ease of cheating in online tests and exams due to students using other electronic gadgets and social media software or sitting in close proximity to each other outside of camera detection range; (iii) Privacy issues of female teachers and students in turning on the camera for classes and exams; (iv) For non-MCQ based subjective exams, time management issues by students, especially in the conversion of written scripts to a form suitable for electronic submission, e.g., scanning of the document requires significant time to be utilized from within exam duration and online submission also becomes tricky due to load on university LMS as the traffic spikes suddenly; and (v) Internet disruptions.

Similarly, during the pandemic outbreak [1], for online class conduction, educational institutes have been favoring either licensed Video Conferencing Systems (VCSs), e.g., Microsoft Teams [6], or freely available VCSs, e.g., Zoom [7]. These VCSs were developed with the prime focus of online meetings and never with the intention of conducting educational classes and exams. Although some specialized online examination modules are developed by Pearson VUE [8], Autoproctor [9], ProctorU [10], etc., there is still a need for the unification of various tools, which have been developed along with recent research studies, to create an online class and exam conducting system that can be seamlessly integrated with the university LMS.

Future LMS will be equipped with AI-based tools for the adaptive learning experience, online proctoring, advanced data analytics and intelligent user session management. These will in turn fuel research into several cross-disciplinary research such as faster hardware technologies to support advanced image and video processing and analytics, user biometrics-based identification/authentication. In addition, they will also require faster, reliable, secure data delivery over the Internet with the help of Software Defined Networks (SDN), advanced data encryption and elastic data applications to support real time, computationally intensive AI-algorithms running at back end.

In addition to these technical challenges, LMS will also be challenged in future with other ethical challenges due to AI based content generation tools that the student will consult for completing assignments. With the recent breakthroughs in Generative-AI technologies like Open AIs ChatGPT and Google Bard, there has been an increasing apprehension by academics that chatbots interfaces provided these technologies utilizing smart AI-algorithms can facilitate a student in plagiarizing assignments that cannot be detected by conventional plagiarism detection tools like TurnItIn [11], IEEE CrossCheck [12], and iThenticate [13]. McIntire et al. [14] used a technique to study the statistical patterns of word frequency in messages and inter-message intervals to detect if student response was indeed generated by a chatbot or not. More recently, several researchers have developed online tools to detect whether responses submitted by students are original work or generated by chatbots such as ChatGPT [15–19]. Thus, one requirement of advanced plagiarism detection software will be to counter AI-algorithms to detect the involvement of a chatbot.

Thus summarizing, LMS development for next generation education delivery will not be limited to just one particular area of research rather it will affect several layers of the OSI protocol stack for networked LMS applications. The main contribution of our work will be to present a comprehensive survey of Artificial Intelligence (AI) based novel techniques as proposed in the recent research literature, e.g., [9–11] in the development of LMSs. These techniques work in the Application, Presentation, Session, Transport, and Network layer in the function of LMSs. This comprehensive survey covers (i) AI-enabled adaptive learning techniques to tailor the course according to individual student needs, (ii) Techniques used for extracting student bioinformatics (fingerprints, face detection, etc.) to authenticate using AI support, (iii) Making the online exams resilient to internet outages, (iv) Automated video surveillance of students attempting exams (eye gaze and face motion tracking) (v) AI-based tools for plagiarism detection (chatbot generated responses or use of prohibited URLs) and (vi) the overall system being more student-friendly and privacy-preserving especially for female students and teachers.

The roadmap of the paper (Fig. 1) will be as follows: Section 2 will describe related work; Section 3 covers the recent developmental trends and research for AI-backed LMSs; Section 4 will present existing research challenges. Section 5 discusses the future trends on the development of LMSs in the presence of generative-AI based chatbots like ChatGPT. Then, Section 6 provides a discussion on the different aspects discussed in the previous sections of this paper. Finally, Section 7 concludes this paper.

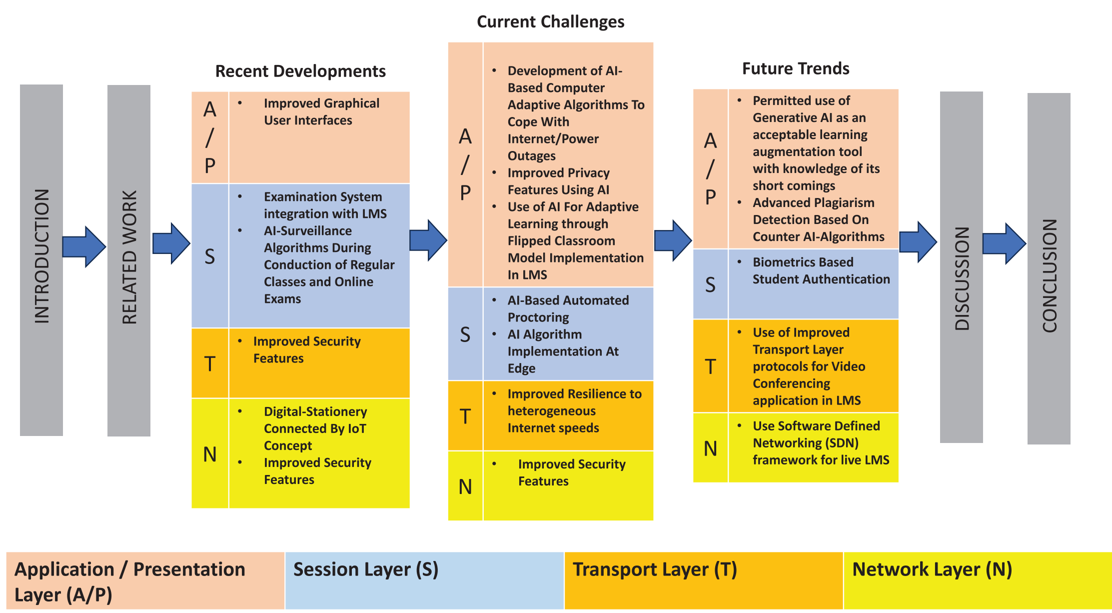

Figure 1: Roadmap of the paper

2 Related Work

With the outbreak of the COVID-19 pandemic, the entire world switched from physical education to an online mode of education. This precipitated the change in the development of effective online educational tools for use in education institutes. Several researchers have investigated the shift in this paradigm [12]. Murad et al. [20] conducted a survey for teacher readiness for the online education system in Indonesia. Mondego et al. [21] conducted a similar study but focused primarily on online teaching techniques that could be used by academicians at higher education institutes. Supriyatno et al. [22] stressed the need for effective teacher training for online educational tools and the institutes to constantly monitor student progress and satisfaction levels. Similarly, researchers have conducted an exhaustive literature review of different strategies and practices adopted by different educational institutes and challenges faced by academics and students in the new online education delivery method. Other researchers have used Twitter data to garner popular public opinion and feedback related to online education during the COVID-19 pandemic. Again, different regulatory processes and effective communication tools were found to be major impediments to ensuring the quality of online education delivery methods. Edy et al. [23] discussed the impact of online education through video conferencing tools such as Zoom, WebEx, Meet, etc., on vocational education, which requires hands-on training by the students. The study found that there were remarkable shortcomings in students' learning outcomes. Salas-Pilco conducted a similar study for STEM education in Latin America [24]. Wang et al. [25] conducted a SWOT analysis for college-level online education.

The use of AI in every aspect of our lives has exponentially increased during the past few years [26,27]. AI systems, as the name suggests, are the systems that are trained using large amounts of data to mimic human brain-like thinking processes and perform routine tasks [28,29]. AI has revolutionized the way we used to perform our day-to-day tasks and has found many applications in education, healthcare, banking, transportation, entertainment, and smart-systems based on Internet of Things (IoT) technology, etc. [30,31]. Al-Chalabi et al. [32] used adaptive learning based on a decision tree algorithm to train students using e-learning tools.

Nenkov et al. [33] developed an AI-based personalized learning system. This system uses agents in the form of AI-powered chatbots to automate the interaction between the student and the teacher using an LMS based on the Moodle platform. Skrebeca et al. [34] considered a very novel approach to automating student-teacher interaction by using lecture delivery methods such as chat messages. Albayrak et al. [35] considered the various applications of AI chatbots in various sectors, such as education, telecommunication, banking, health, customer call centers, and e-commerce. Deveci Topal et al. [36] conducted an experimental online course delivered via a chatbot application for 5th grade science course; although results about their performance enhancement in the course remained inconclusive, the students rated the learning experience via chatbot application as superior. However, Yang et al. [37] reported significant improvement in medical students' suturing and ligature training through the use of AI-assisted tutoring in conjunction with clinical studies. Krishnan [38] and Schwendicke et al. [39] have advocated the use of AI-based modern learning techniques in the field of Oral and Maxillofacial surgery and dentistry.

Rahman et al. [40] studied the technical programming challenges for several cloud-based chatbots such as IBM Watson, Microsoft bot, AWS Lambda, Heroku, and many others. OpenAI has quite recently introduced a conversational chatbot popularly called ChatGPT [41]. This chatbot is developed on the Generative Pre-trained Transformer (GPT) language model, which is precisely trained to produce human-like output in response to user inputs in natural language [42]. Deep learning and natural language processing techniques are used to train ChatGPT on massive amounts of text data to understand human language [43]. ChatGPT is the latest state-of-the-art chatbot from OpenAI, which has shown that its system can generate passing grade-level responses to several graduate-level bar and medical examinations [44]. King et al. [45] included ChatGPT as a co-author in their journal article, while ironically, other research publications disapproved of using chatbots as a co-author.

Ranoliya et al. [46] considered the problem of AI-based chatbots for answering student FAQs about a university. To address this problem, in this paper, the authors propose the design of a chatbot using AI-Markup Language (AIML) and Latent Semantic Analysis (LSA). Ugurlu et al. [47] tackled the same problem by designing an AI-based virtual assistant through a chatbot for a Turkish University. Wang [48] discussed the fusion of AI and virtual reality technology for university-level physical education.

Chiang et al. [49] used deep learning algorithms for the prediction of student performance in introductory computer programming courses using Moodle-based LMS log data. Aljaloud et al. [50] conducted a similar study by employing a combination of convolutional neural networks (CNNs) and long short-term memory (CNN-LSTM) to predict student information using LMS data. Another study carried out by Akmese et al. [51], in which the author found that student academic performance prediction based on their social and demographic situation could be effectively predicted through the Random Forest Machine Learning algorithm.

Slusky [52] presented a comprehensive literature survey on several commercially available online examination systems developed by PearsonVUE [8] ProctorU [10], Eklavya [53], Respondus [54], Talview [55], etc., and used an online proctoring system to prevent cheating. Requirements and capabilities of various commercially available online exam proctoring systems have been critically analyzed by Nigam et al. [56].

Chiu et al. [57] considered the application of AI to the field of education in four key educational domains, i.e., learning, teaching, assessment, and administration, and presented a thorough bibliographical survey. Salas-Pilco [58] considered the effects brought about by AI and robotics on the intellectual learning outcomes of students in higher education.

Vahabzadeh et al. [59] developed AI-based smart glasses for the learning experience of autistic students as a tool for their social and emotional behavioral learning aid. Another study carried out by Standen et al. [60] discusses the use of AI-algorithms for adaptive learning approaches for individuals with learning disabilities. McCarthy et al. [61] developed an AI-based tutor for teaching braille language to blind individuals.

Sun et al. [62] and Chen et al. [63] discussed the applications of blockchain technology in the field of online education for secure storage of learning records, course credibility, credit and certificate certification, student privacy, and course sharing. Blockchain technology [62,63] can store such data in a trusted, distributed manner, provide credible digital certificates, realize learning resource sharing with smart contracts, and protect intellectual property through data encryption.

Villegas-Ch. et al. [64] utilized an AI-model and implemented it through a Hadoop framework for efficient prediction of learning activities tailored to the needs of all students. The AI-system processes the student's past performance information and recommends activities that focus on each student's abilities and needs. The practical integration of these systems into universities' LMSs can create an adaptive educational model that responds to the new challenges of society. Sharma et al. [65] also applied a machine learning approach to provide students with timely, actionable feedback to improve their academic performance in a futuristic adaptive learning environment. Tsai et al. [66] provided a similar solution using a Deep Learning model.

3 Recent Developments Towards Making Smart LMSs for Online Education Delivery

The requirements of an effective online LMS are multifaceted. It should incorporate an AI-enabled adaptive learning approach, accurate student authentication, and online proctoring algorithms, amongst other features. Currently, the universities start with a video conference application program (either licensed or free) and tailor their exams to work around it. It is necessary to make a secure, online class conduction and exam system at the forefront of the design, which will have both hardware and software components to authenticate the exam candidate and prevent cheating or other unethical means. The proposed architecture is shown in Fig. 2.

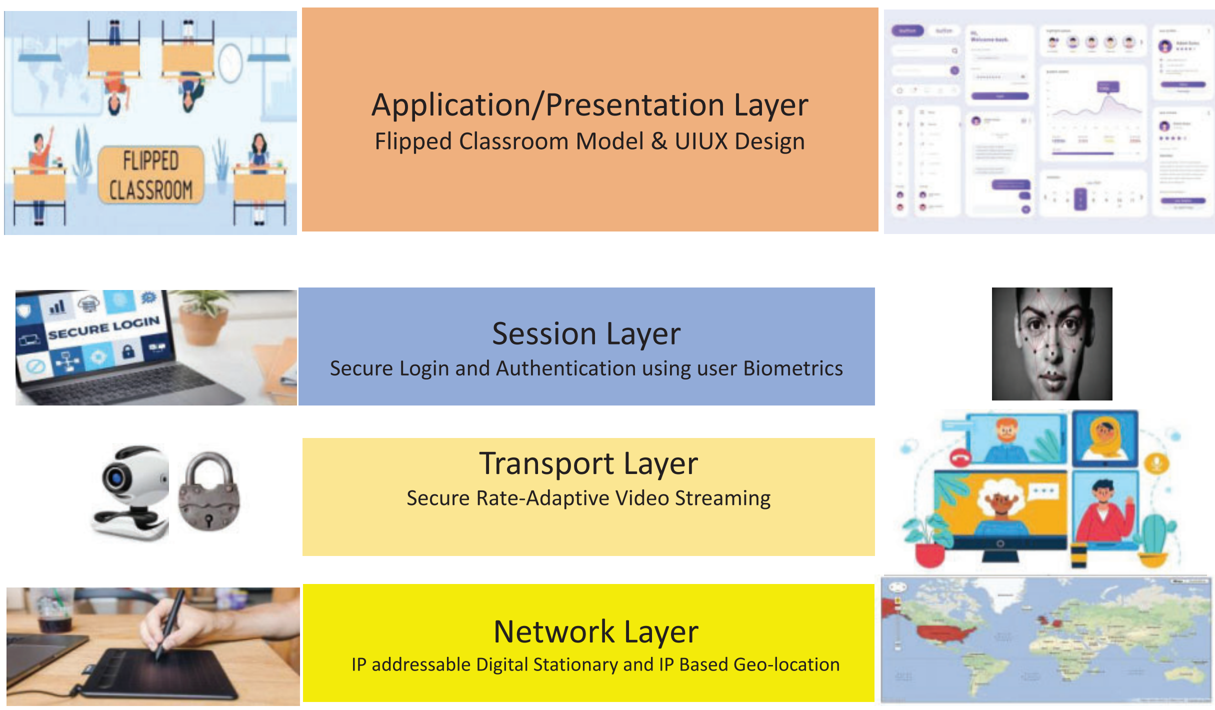

Figure 2: Overall semantics of an AI-integrated LMS architecture

3.1 Improved Graphical User Interfaces–(Application/Presentation Layer Enhancement)

Modern Learning Management System uses intuitive graphical user interfaces so students can easily interact with it. The user interface includes icons, buttons, menus, search bars and also provision for online tools through hyperlinked third-party software tools. This greatly speeds up the learning interface for students and faculty alike. Through improved user interfaces, learning management system (LMS) provide easy-to-use tools for the administration, documentation, tracking, reporting, automation, and delivery of educational courses, training programs, materials or learning and development programs.

3.2 Development of an Examination System Integrated with LMS–(Session Layer Enhancement)

Currently, the online examination systems supported by open-source LMS of universities can only support a variety of online exam types, e.g., Subjective, Objective, and MCQs. However, the prevention of unfair means in attempting the online exam can be partially guaranteed for MCQ-based exams through measures such as time limits on a question and scrambling of questions and answer choices for candidates, and that too is only applicable when students attempt the exam in specially controlled conditions, e.g., a dedicated exam center only. In other types of non-MCQ-based exams, i.e., numerical-based, subjective, or theoretical, limited techniques have been developed for Massive Open Online Courses (MOOCs), so it is easier for the candidates to use unfair means in online exams on this pattern.

Under the new Outcome Based Education (OBE) systems [1,3], it is mandatory to judge the candidate's performance on non-MCQ-based exams to measure their course learning outcomes (CLOs) and program learning outcomes (PLOs) [3]. To alleviate this problem of unavailability of video-based online proctoring in LMSs based on the open-source, popular Moodle architecture, usually 3rd party VCSs are used for online proctoring, while the exam paper and completed exam may still continue to be shared through the official LMS channel. As a consequence, (1) The student has to open two software simultaneously to be able to attempt the online exam; (2) As these 3rd party software are not integrated with the LMS, this effectively creates a hurdle in automated solutions for proctoring, a human still has to manually watch the video feeds of all students. Hence, many automated tasks like face recognition and handwriting match, which could easily be performed if these systems had access to LMS data, are not possible.

Many recently developed 3rd party online examination tutoring software are providing additional support for seamless integration with current learning management platforms of universities like Moodle [67], Canvas [68], and Blackboard [69] through open-source customizable plugins. These include ProctorFree [70], HonorLock [71], and Mercer-Mettl [72].

3.3 AI-Surveillance Algorithms during Conduction of Regular Classes and Online Exams–(Session Layer Enhancement)

One of the significant issues identified by university academics is that while taking virtual online classes through any video conferencing systems, due to the absence of face-to-face contact, it is often difficult to track which student is present and actively participating in the lecture or merely logged into the VCS. Videos are often switched off due to privacy concerns, especially for female students or when the internet bandwidth is low. A more dire situation may be another proxy student attending the lecture and attempting quizzes/exams on behalf of an enrolled student.

Similarly, during the conduct of the exams, it is difficult to detect any means of unfair cheating by the students. In fact, the use of unfair means is common, especially for subjective exams. Tarigan et al. [73] conducted an exhaustive literature review for different types of academic misconduct by the students attempting online exams. Rabiha et al. [74], in their literature review, drew the conclusion that the most popular online cheating detection techniques used in popular literature were facial motion and head pose, followed by eye movement or gaze detection. Finally, in the third place were the facial movements and gaze detection for multiple targets, as depicted in Fig. 3.

Automated AI-algorithms will be able to establish the identity of the candidate through advanced Face Recognition algorithms. Similarly, Advanced Handwriting checks on answer scripts submitted by students, which is not possible to be done manually by teachers, given a large number of students. This may be managed by implementing CNN algorithms to implement AI-based surveillance of students attending lectures, submitting assignments throughout semesters, and online examination invigilation.

The CNN algorithm architecture is shown in Fig. 4. In this architecture, during the normal conduction of semester classes, student pictures, and their handwriting samples may initially be pulled from the LMS database as a first instance of a labeled dataset sample. More training data of student pictures and handwriting samples can be generated during the normal progress of the semester to allow the CNN to train up to an acceptable level before its implementation can be allowed with low false positives and false negatives. Initially, to validate this training dataset, occasionally, the CNN will take manual help from the professors to limit any errors in the training dataset. In a standard 50-min lecture duration, a considerable amount of labeled datasets for visual student recognition can be generated.

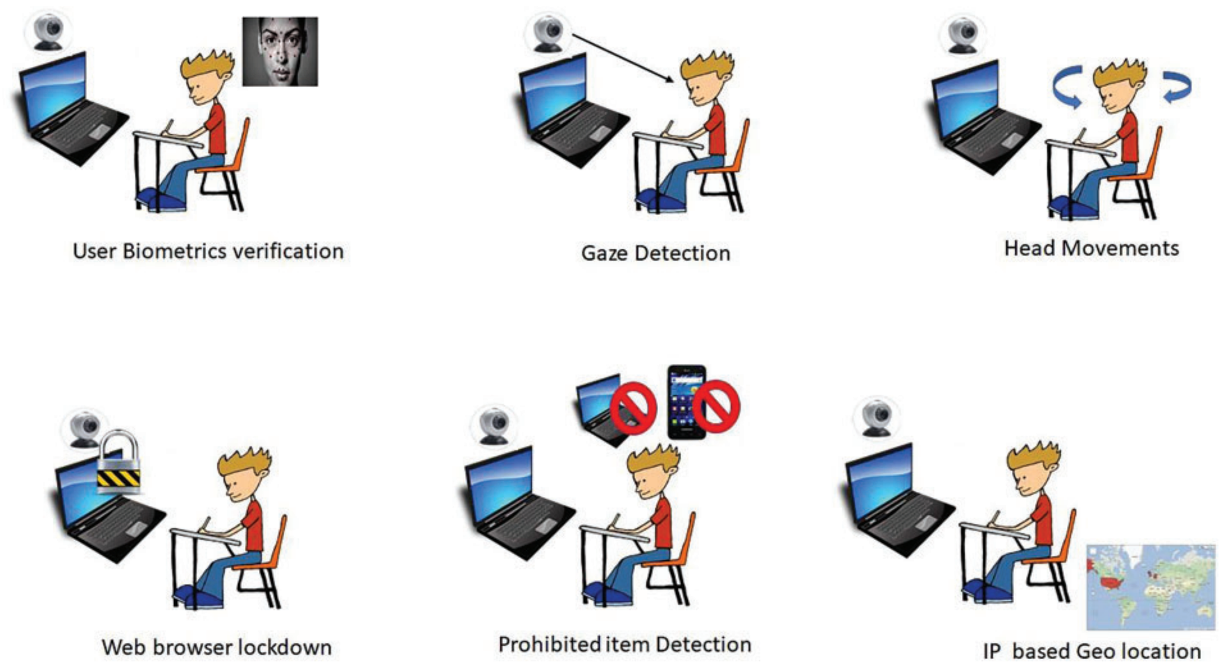

Figure 3: Common features of online proctoring solutions

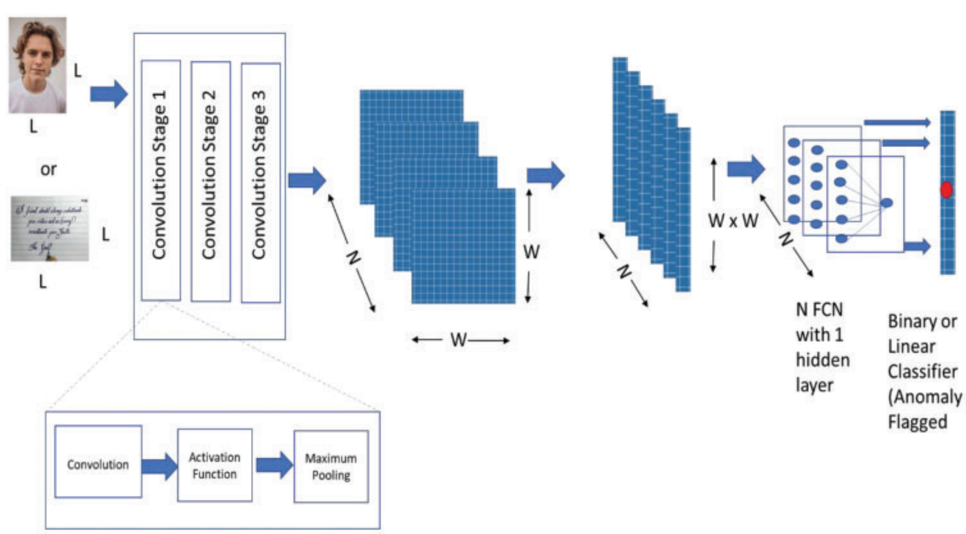

Figure 4: CNN architecture to reliably establish the identity of a student using real-time face recognition or handwriting match

Similarly, ample amounts of handwriting samples can be obtained from student assignments/quizzes being submitted through university LMS systems. In advanced stages, such student data can also be carried forward to subsequent semesters. The above architecture can determine with high accuracy if a student's identity can be established reliably from the match of this video/image data and handwriting samples. An anomaly will be appropriately flagged for manual investigation by the college administration. Also, valuable statistics can be gathered about the learning experience of students through online education [75] and an evaluation system [76].

Li et al. [77] developed a multi-index cheating detection technique using an LSTM neural network. Similarly, Samir et al. [78] and Essahraui et al. [79] developed a cheating detection system for onsite as well as online examinations by introducing novel computer vision techniques based on CNN-Facial-Landmarks and LSTM models for the classification, which incorporate the detection of students' head postures and hand movements during the conduction of an online exam. The algorithm can detect cheating for both single-user and multi-user tracking scenarios.

Yulita et al. [80] developed an efficient classifier based on the combination of AdaBoost and SVM for cheating detection using datasets of human activity detection. They found that the proposed approach was more efficient in the detection of cheating compared to other machine-learning techniques. Li et al.[81] developed an online proctoring application by using two cameras working in tandem for 3D gaze tracking. They developed novel gaze motion formulas and also trained a custom-built object detection classifier to detect cheating targets in exams.

Dilini et al. [82] used a One-Class Support Vector Machine (OCSVM) technique for student gaze-based cheating detection. Gupta et al. [83] have developed a smart Bluetooth-based camera application for online exam cheating detection even if the student is taking the exam at his home using the Deep Learning approach. Rudian et al. [84] indicated security vulnerabilities for digital content generation in online lecture delivery and exam creation using H5P, where often the answer to a question can be easily obtained using the source code itself used to develop the exam. They suggested useful measures that can be used by the instructors in setting the question papers in these situations.

Kasliwal [85] used an open-source packet-capturing application, KISMET, for packet sniffing at the student's computer to see if the student used any of the prohibited URLs during the exam. Bawarith et al. [86] used student biometric authentication via fingerprints, eye tracking, and motion detection techniques via embedded hardware to determine any suspicious activity by the student attempting the online exam.

Atoum et al. [87] developed a multimedia analytics system that continuously tracks six features for the duration of the online exam; gaze detection, text detection, voice detection, phone detection, active window detection, and user verification.

There are a few AI-based software that also help bridge the gap between online lectures and online examinations. One such software is Examus, which monitors students' behavioral characteristics during online lectures and provides them with proctoring services for better monitoring in online exams [52]. Table 1 provides a summary of research in this domain utilizing AI-based smart algorithms.

Table 1: Summary of research works in the domain of artificial intelligence for academic misconduct prevention in online exams

Research work or commercially available proprietary software	Technique for prevention of academic misconduct in online examination	Artificial intelligence algorithm
Talview [55]	Synchronous and asynchronous use of recorded audio-video streaming and screen snapshots capturing user's computer activities	Proprietary video tracking software
Yulita et al. [80]	Machine learning classification algorithm (on datasets) for human activity detection	Adaboost + SVM
Li et al. [81]	Two camera applications for 3D gaze tracking and cheating target detection	Custom-built gaze motion formulas and cheating target detection based on custom-built object detection classifier
Dilini et al. [82]	Eye gaze detection	One class SVM (OCSVM)
Gupta et al. [83]	Smart Bluetooth-based camera application	Deep learning technique
Samir et al. [78] and Essahraui et al. [79]	Head posture and hand movements	CNN-facial-landmark, media pipe models. And LSTM classification model for cheating case prediction
Atoum et al. [87]	Voice detection, user verification, text detection, gaze estimation	Multimedia analytics
Rudian et al. [84]	Security vulnerabilities of software used in the development of online exams such as H5P	NA
Kumar et al. [88]	Handwritten character recognition for writer identification	RNN and LSTM, mixture density networks, reinforcement learning, generative adversarial networks
KreB et al. [89]	Real-time handwritten character recognition with a in pen interface	Deep neural networks (DNN) employing connectionist temporal classification (CTC) algorithm and language models to the decoding algorithm

(Continued)

Table 1 (continued)

Research work or commercially available proprietary software	Technique for prevention of academic misconduct in online examination	Artificial intelligence algorithm
Rajesh et al. [90]	Handwritten character recognition for conversion to text suitable for plagiarism detection	Convolutional neural network (CNN) and Bi-Directional long short-term memory (BiLSTM) based recurrent neural network (RNN)
Aljaloud et al. [50]/ Akmese et al. [51]	Student performance prediction in online courses and exams	CNN + LSTM applied on blackboard/Random forest algorithm
Pareira et al. [91]	AI-based recommender system for POJ (Programming online judges) to select questions for assignments to avoid plagiarism and detect student efforts in completing the assignment	Custom built AI-based recommender system
McIntire et al. [14]	Chatbot-generated response detection	Words per message, inter message delays
GPT zero [15]	Chatbot-generated response detection	Not mentioned
Open AI GPT2 output detector [16]	Chatbot-generated response detection	Transformer model
ContentScale AI content detector [18], writers AI content detection [19]	Chatbot-generated response detection	Not mentioned
Kasliwal [85]	Packet capturing and detection of prohibited URLs	KISMET open-source packet capturing application
Bawarith et al. [86]	Authentication using student fingerprints and continuous eye tracking and motion tracking	Embedded hardware digital persona U. Are.U 4500 HD USB fingerprint reader, and eye tribe tracker
Respondus [54]	Respondus LockDown browser keeps open only one browser and disables access to the rest of the endpoint (user computer) environment. Respondus monitor checks students' behavior by using a webcam and performs video analytics to detect behavioral events that can signal cheating during online exams	Respondus LockDown browser and respondus monitor proprietary software

(Continued)

Table 1 (continued)

Research work or commercially available proprietary software	Technique for prevention of academic misconduct in online examination	Artificial intelligence algorithm
BeyondTrust privilege management [92]	Secure administrative privileges and access management for the examinee's computer	Proprietary software

3.4 Digital-Stationery Connected by IoT Concept–(Network Layer Enhancement)

Another challenging issue faced by teachers is that students may submit work completed by another student, passing it off as their own. Sometimes, images of handwritten work are not legible. In this solution, students will attempt the exam using Digital Writing pads, which will make the job of handwriting recognition simpler and faster. Also, such digital stationery will credibly establish the real-time geographic location of the exam candidate throughout the duration of the exam, even in the absence of video surveillance. Liwicki et al. [93] made the case for handwriting detection through pen-enabled displays/tablets for instant handwriting recognition.

AI-algorithms can then be used for real-time detection of handwriting. Similarly, Kumar et al. [88] made a case for using an AI-algorithm for handwritten character recognition for writer identification using Recurrent Neural Networks (RNN) and LSTM networks. KreB et al. [89] proposed a Deep Neural Network (DNN) based technique in which sensor data is first stored in a compressed format in the electronic pen through quantization of weights of the DNN layers. Then, a Connectionist Temporal Classification (CTC) algorithm is used to minimize the link bandwidth. This allows transmitting only a small matrix from the pen to the mobile device on which the decoding is performed. Additionally, to further improve the accuracy of handwriting recognition, the authors added a Language Model (LM) to the decoding algorithm executed on the mobile device. This technique distributes the load on the hardware while making edge computing possible for handwriting recognition.

3.5 Improved Security Features–(Transport and Network Layer Enhancements)

Respondus [54], a commercially available software that uses Respondus LockDown Browser, keeps open only one browser and disables access to the rest of the endpoint (user computer) environment. Respondus can monitor students' behavior by using a webcam and perform video analytics to detect behavioral events that can signal cheating during online exams. Similarly, BeyondTrust Privilege Management [92], another commercially available software, is an endpoint security software that combines privilege management, application control, and sandboxing. It helps prevent unnecessary granting of admin rights to users and compromising security by enabling users to log on to the desired applications using their standard user accounts. This is done by limiting traffic to only applications using specified TCP port.

Another but limited solution for securing access control is a virtual private network (VPN). Some already available applications like Sonicwall [94] enable restricted and secure VPN access and firewall solutions for higher education examination purposes.

4 Current Challenges

4.1 AI-Based Automated Proctoring: Reliable? (Session Layer Enhancement)

There is an increasing concern about the shift of control from academic institutions to commercial providers, as investigated by Selwyn et al. [95]. The AI-algorithms can frequently make mistakes or out-of-context decisions as they are only as good as they are 'trained.' Henry et al. [96] brought to light a case of a student who was disqualified from an online exam by an online proctoring algorithm, only to be reinstated swiftly when she lodged a formal appeal against the decision, with the professor apologizing for the mistake made by the software. There is a dire need to establish the amount of autonomy academic institutions are willing to give to automated algorithms for all academic misconduct during online examinations while exonerating their own faculty members completely if any student is unjustly marginalized. Also, there is a need for special grievance policies should a student decide to contest a decision made by an automated AI-algorithm.

4.2 Development of AI-Based Computer Adaptive Algorithms to Cope with Internet/Power Outages–(Application/Session Layer Enhancement)

Computer adaptive testing was established three decades ago by international testing services like ETS for GRE exams. The questions appear from different difficulty level pools and try to zero in on the true academic potential of the student. Newer initiatives [97] follow a two-pronged approach for harnessing AI in effective learning of students using both adaptive and adaptable learning. Another issue that can be solved using this approach is that conventional LMS systems based on Moodle architecture only run the exam timer on the main LMS server. Sometimes, internet disruption during time-limited exams proves disastrous for candidate's performance in the exam when they miss valuable examination time in the event of client-side computer problems such as internet or power outages. It is necessary to have a seamless examination system in which the adapted examination system can run locally on the client side and an encrypted version of the past time-stamped student responses be saved on the local computer with a local timer operating on the local (client side) computer with candidate's browser and audio/video logs which could be submitted as soon as Internet service is restored.

4.3 Improved Privacy Features Using AI–(Application Layer Enhancement)

Female teachers and students are reluctant to turn on their videos during the conduction of online classes and exams due to privacy reasons that any videos recorded in the class or during exam invigilation could be used by cybercriminals. Due to this, many female teachers opt for an asynchronous mode of online classes, or the conduction of live classes with the video turned off. This creates learning issues for many students. Similarly, female students are reluctant to have their video recorded while conducting online exams. Thus, privacy issues are at the forefront for both female teachers and students, as highlighted in recent research [98]. Student has frequently expressed concerns about online proctoring systems recording private and sensitive information from their computers [99,100]. Online education systems should safeguard these concerns so that female teachers and students are able to share their videos with their privacy concerns addressed using encrypted video streams [101–103] and advanced AI-based algorithms to still be able to carry out their face detection accurately even with the presence of hijab/niqab [104–106]. There is also an increasing concern about ethics when handling students' and teachers' private information; this has been discussed in detail by Henry et al. [96].

4.4 Improved Resilience to Heterogeneous Internet Speeds–(Transport Layer Enhancement)

The other important issue is that the students connecting to such online video conferencing systems connect through different networks with different connection speeds and bandwidths. Turning on high-resolution videos for multicasting puts needless strain on the network, and often, universities advise teachers and students to keep their videos turned off. This again exacerbates the issue of students using unfair means during regular classes and exams. Top automated proctoring solutions commercially require high bandwidth internet connections for satisfactory performance. Pearson VUE online proctoring software requires at least a 3 Mbps connection [107]. Elastic applications with rate adaptation according to network conditions have been developed using efficient transport layer algorithms, as shown in Fig. 5.

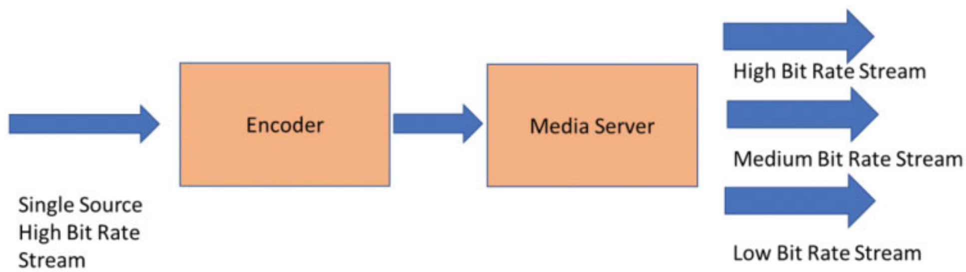

Figure 5: Rate-adaptive data streaming

Notable works in rate-adaptive video streaming applications include Dynamic Adaptive Streaming over HTTP (DASH) [108], and HTTP Live Streaming protocol (HLS) [109], which adapt the bit-rate based on network conditions. DASH divides videos into segments and applies H.264 [102] or HEVC advanced video coding [110] to encode them at varying quality levels (bit-rates). These encoded segments are then stored on the server. The client selects the most suitable segment to transfer the video based on the current network capacity estimation. Another viable option for real-time video streaming is by using Software Defined Networks (SDN). Service providers can interact with apps and devices through a programmable interface provided through SDN. This gives consumers the ability to negotiate bitrate streams for real-time services and make quick requests for resource allocation for various services. The SDN design offers a method for separating network control and routing duties, leading to programmable and abstracted control that is unrelated to network services and applications. SDN makes it feasible to design flexible topologies and new protocol extensions for networks. Only a few emulators, including Mininet [111] and OpenVswitch [112] are readily available right now.

Like rate-adaptive data transmission schemes to salvage real-time data transmission in the face of internet outages, legacy data compression may also be used, albeit for non-real-time or near real-time applications. KreB et al. [89] proposed a handwriting recognition technique using an electronic pen in a deep neural network (DNN) technique in which sensor data is stored in a compressed format. This allows transmitting only a small matrix from the pen to the mobile device on which the decoding is performed. Similarly, Rajesh et al. [90], in their work, HWRCNet, developed a data-compression-based handwritten characters recognition technique combining CNN and Bi-Directional LSTM (BiLSTM) based RNN.

4.5 AI-Algorithm Implementation at Edge–(Session Layer Enhancement)

It is also important to implement AI-algorithms at the edge through the IoT concept [113], which will make the system secure [114], and scalable and reduce the burden on a centralized AI inference engine for real-time cheating detection. Online proctoring is heavily dependent on real-time computer vision algorithms. These advanced computer vision algorithms run on the server-end. In the event of session disconnection due to a real or doctored internet/power outage, the computer vision processing will cease giving an opportunity to students for academic misconduct. If these algorithms are running at the edge, i.e., client-end, then automated proctoring can continue unabated and also notify the central server if any anomaly is detected at any point in time.

4.6 Use of AI for Adaptive Learning through Flipped Classroom Model Implementation in LMS–(Application/Presentation Layer Enhancement)

Varnavsky [115] investigated the efficiency of Flipped Classroom technology using chatbot-based student interaction. Pareira et al. [91] devised an intelligent system where an AI-based recommender system proposes tasks for student assignments in computer programming courses to avoid plagiarism and truly reflect students' efforts by monitoring the IDE used to develop the assignment. Initiatives like [97] follow a two-pronged approach to harnessing AI in the effective learning of students. AI-based adaptable and adaptive learning is possible through both a mobile and web interface. A learner can learn what he is capable of learning (adaptive) and in the manner he wishes (adaptable learning). The system, through deep data analytics, determines the contents of the course and the manner in which it should be presented to enhance the learning of the student as per previous attempts in completing assignments and tests. An intuitive UIUX design is also a must to support enhanced user experience.

5 Future Trends on the Development of Learning Management Systems

5.1 Permitted Use of Generative-AI as an Acceptable Learning Augmentation Tool–(Application Layer Enhancement)

Future education delivery including that using LMS, will be highly affected by generative-AI based content generation and knowledge discovery tools. The popularly available ChatGPT AI-chatbot to everyone including students is trained on a vast amount of data available from the Internet, and its GPT technology allows it to produce human-like responses to various input prompts. ChatGPT is an advanced language model that utilizes the "transformer architecture" to perform various natural language processing tasks such as language understanding and generation [116]. This unique architecture enables AI-powered chatbots to interpret the relationship between words in a sentence, thereby preserving context and producing responses that are both logical and coherent [117]. In engineering, sciences, and related research disciplines, this leads to technical content generation like experimental protocols, designs, and results [118]. When it comes to research content writing, the ChatGPT-based approach offers a significant advantage in terms of efficiency. Writing papers or a thesis can be a time-consuming task, but with this method, users can save time and effort by receiving instantaneous relevant responses from ChatGPT based on specific input prompts related to their research areas. Technical knowledge and area expertise are crucial for engineering and scientific research paper writing, which can make it quite challenging. However, the use of ChatGPT AI-chatbot can be of great help, as it can generate relevant content based on carefully drafted prompts provided by the researcher, thus saving time and effort in the writing process [119]. Another advantage of utilizing ChatGPT-based AI-chatbot for scientific and engineering research paper writing is the potential to enhance the consistency and precision of the way the papers are written. Publishers like IEEE, Springer, Elsevier, Wiley, etc., who publish technical research papers generally demand a high level of accuracy and consistency from the authors, which can be difficult for human writers (especially those who do not have English as their first language) to maintain consistently. ChatGPT-based techniques can produce a dependable and precise output, decreasing the likelihood of errors and disparities [120].

However, ChatGPT also has some limitations. One of the major drawbacks of the ChatGPT model is its lack of deep understanding and potential to produce erroneous or faulty information. ChatGPT is trained on a vast amount of data (from the internet) that could contain inaccuracies or biases, resulting in the model generating misleading information. Furthermore, the model may not possess the required proficiency to create highly precise technical content, particularly for specialized fields where area-specific advanced domain knowledge is required [121]. As an AI-powered assistant, ChatGPT has limitations when it comes to assessing the credibility of its training data, which can affect the accuracy of the information it generates [16]. Moreover, ChatGPT does not have access to the Internet and currently has limited knowledge of world events after 2021 [122,123]. Therefore, some of its responses may be outdated or inaccurate since knowledge is continuously evolving, and its training data set is outdated. For example, when ChatGPT is required to produce up-to-date references for any specific area, ChatGPT may provide fabricated references that seem plausible but are not backed by real-world sources [122].

One drawback of utilizing ChatGPT in the scientific and engineering disciplines for research paper writing will be its potential to lack the creativity and tone that human writers possess. Writing research papers requires more than just providing accurate and consistent data; it also involves effectively conveying complex information in a clear and simplistic manner. The use of ChatGPT may result in less engaging and effective output due to its possible lack of creative and nuanced writing [122]. Another disadvantage is that ChatGPT-based scientific and engineering written content could be biased as per the training dataset and algorithm design, etc., which is one of the biggest problems in AI-powered chatbots because they lack the basic human touch in writing and hence avoid the biases. As per the principle of 'garbage-in-garbage-out,' AI-powered chatbots have the potential to reinforce biases by utilizing large sets of data that already contain these biases [124].

5.2 Advanced Plagiarism Detection Based on Counter AI-Algorithms–(Application Layer Enhancement)

In academia and research, the use of ChatGPT as an AI-powered chatbot with the ability to generate text that resembles human language has sparked several ethical concerns related to academic dishonesty [113,119,125]. Although ChatGPT's responses are not exact copies of any specific text, they are generated by synthesizing training data, which may lead to producing responses similar to those of existing sources. A recent test [116] has shown that ChatGPT wrote a 500-word essay that had a 45% similarity to existing sources. The danger is that students might use ChatGPT without realizing the potential for plagiarism [121]. Moreover, ChatGPT's ability to generate research studies and scientific abstracts with fabricated data poses a significant risk to academic integrity [121]. This capability may encourage higher education students to rely solely on ChatGPT when writing academic essays, which leads to academic dishonesty. Furthermore, ChatGPT's tendency to generate incorrect and nonsensical answers raises the risk of misinformation in scientific publications, making this ethical issue even more serious.

As generative-AI based content generation tools are beginning to emerge, proponents will advocate their use as long it is responsibly acknowledged by the student. The AI-chatbot, ChatGPT, is extremely popular, but academics and researchers all over the world are worried that excessive use of ChatGPT in technical research papers and thesis writing [122] will result in sub-optimal research efforts. Academicians and researchers predict that the uncontrolled use of ChatGPT can be quite catastrophic for the research community in general and the scientific and engineering research fraternity in particular [123]. Some alarming facts show that ChatGPT has demonstrated its capacity to provide satisfactory responses to exam questions in medical and legal fields [118,123]. An empirical study revealed that ChatGPT's answers to life support exams at a university were, on average, relevant and accurate and more closely aligned with guidelines than previous studies that utilized other AI tools. Given this level of performance, ChatGPT poses a significant threat to academic integrity, particularly in higher education [122].

To overcome the problem of plagiarism, counter AI-detection tools like GPTZero [15] are already in use. These tools can predict if a certain text was potentially generated by generative-AI software by analyzing the linguistic constructs in the text [125]. Moreover, quite recently, Turnitin similarity index checking software has also introduced a new option in their software which checks the AI involvement in the written text [11].

5.3 Biometrics-Based Student Authentication and Behavior Prediction–(Session Layer Enhancement)

Authenticating the identity and behavioral patterns of the student studying or taking exams in distant (online mode) is one of the biggest future areas of research for LMS development. Advanced image/video processing techniques backed by AI will be required for biometrics-based student authentication and behavior detection [126–130]. Previously available techniques, such as Face recognition, have often been shown to be easily deceived if a photo of an individual is presented to a camera. The new research direction will focus on diverse student biometrics-based user identification such as fingerprint, handprint, and iris detection using commodity webcam or smartphone cameras. Biometrics-based student authentication will be a big step toward the prevention of academic misconduct in online lecture delivery and exams.

5.4 Use of Improved Transport Layer Protocols for Video Conferencing Applications in LMS–(Transport Layer Enhancement)

User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) are the most commonly used transport layer protocols for elastic data delivery on the Internet. This covers data delivery with different QoS requirements, such as latency-sensitive or non-real-time data delivery. Of these, UDP is preferred for real-time data applications, and TCP is used for stored video streaming. TCP ensures reliable data transmission through variable data-rate on the basis of receiver feedback; it does so by retransmitting any lost data packets, making it unsuitable for any real-time video transmission. UDP uses fixed-rate data delivery irrespective of network conditions. Transmitting lower-resolution video quality or a video with many lost frames may compromise the effectiveness of AI-algorithms used for online proctoring and other tasks. AI-algorithms used for advanced video analytics need to work with higher-quality videos. Modern LMS video conferencing applications will use a combination of TCP and UDP for video transmission. TCP will be used for the control plane for probing the network, and UDP will be used in the data plane for flexible rate data delivery, ensuring acceptable QoS. Newer transport protocols designed for video content delivery, such as those used for online lectures through LMS, are becoming increasingly popular. These protocols are equipped with advanced network probing algorithms, such as PathRake TCP [131], which allow for efficient estimation of available bandwidth, even in the presence of firewalls on the network path. The use of these protocols will greatly improve the user's quality of experience.

5.5 Seamless Communication of Smart Cameras with Software Defined Networking (SDN) Framework for Live LMS Sessions–(Network Layer Enhancement)

Legacy routing service on the Internet over TCP/IP protocol is only providing the best-effort service for data delivery on the Internet. Currently, LMS applications use these conventional routing services for video conferencing applications for online classes/exam conduction. The result may be sub-optimal as end users may be connected with variable connection speeds. In addition, network conditions may fluctuate with time. Specialized video conferencing applications, such as Zoom, use peer-to-peer data delivery methods to optimize video transmission, which provides additional network probing service to gauge the network conditions to quickly reroute packets in events of congestion on default routes. LMS applications of the future will instead rely on the Software-Defined Networking (SDN) framework, which gives the network the ability to re-route data packets quickly in the event of Network Failure or if the path does not meet the user QoS requirements, providing seamless service offering dedicated QoS without any involvement of LMS application for network probing service. In the future, segregated data services in the LMS applications requiring different QoS may use different routing services in the network. Real-time video delivery in future LMS will integrate smart cameras instead of regular webcams, which could interact seamlessly with SDN controllers [132] directly while the remaining latency-insensitive non-video data service could use conventional routing services. The SDN controllers will work on adaptive routing protocols to optimize QoS [133] for efficient video delivery to be processed by AI-based image/video processing algorithms at the server end.

6 Discussion

The future of education will likely involve distance-learning (online) techniques facilitated through advanced Learning Management Systems. These changes will be primarily driven by already available advancements in real-time data streaming and enhanced data security and QoS. However, AI-driven advanced applications will be running on top of them to enhance the user learning experience through AI-based adaptive learning strategies tailored to individual needs. These will further be used to credibly authenticate and examine the individuals. AI-backed deep data analytics will help in the evolution of course contents and devise new AI-based adaptive learning strategies to meet course learning objectives and outcomes. However, AI offers equal opportunities for examiners and examinees to benefit from them. Learning Management Systems will always have to be one step ahead of state-of-art techniques and be equipped with counter AI-algorithms.

7 Conclusion

AI-based adaptive learning techniques have long been in development in various civilian, industry, and military sectors due to their proven benefits over conventional training. In particular, the university and vocational education are areas where remarkable benefits have been seen when using AI-based LMS in comparison to conventional modes of lecture. However, the recent COVID-19 pandemic has spurned a renewed interest in addressing previously unanticipated and unexplored research and development challenges. This is because all previous development efforts were made assuming that the trainee could be brought for training into a specialized facility having proprietary hardware and software. However, during COVID-19, the online training had to be imparted to individuals who were geographically separated and connected through heterogeneous technologies involving COTS hardware and open-sourced 3rd party software and various network speeds, causing all sorts of equipment compatibility issues. This article presented an exhaustive literature review covering all facets of AI-based techniques used recently by researchers to address the different challenges mentioned above. This paper also presented the challenges that are yet to be overcome in the current state-of-the-art research for the development of AI-based LMS. These include challenges of real-time online proctoring solutions for academic misconduct detection, privacy challenges, rate-adaptive video-conferencing applications, the delegation of server-centric and client-centric tasks in the face of internet/electricity outages, plagiarism detection for generative-AI responses, and more well-informed grievance procedures and policies if students challenged any of the AI-driven decisions among others.

To conclude about the strengths and weaknesses of ChatGPT, utilizing it for scientific and engineering research paper writing can save valuable time and energy while enhancing precision and uniformity. Nonetheless, these approaches may produce flawed or erroneous content and fall short in conveying the originality and details which can be covered by human authors. It is essential to carefully consider the advantages and disadvantages of ChatGPT-based methods before implementing them for the generation of technical content.

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