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Development of an automated online proctoring system

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ABSTRACT

The rapid development of machine learning technologies, the increasing availability of devices and widespread access to the Internet have significantly contributed to the growth of distance learning. Alongside distance learning systems, proctoring systems have emerged to assess student performance by simulating the work of a teacher. However, despite the development of image processing and machine learning technologies, modern proctoring systems still have limited functionality: some systems have not implemented computer vision methods and algorithms satisfactorily enough (false positives when working with students of different ancestry, racial background and nationalities) and classification of student actions (very strict requirements for student behaviour), so that some software products have even refused to use modules that use elements of artificial intelligence. It is also a problem that current systems are mainly focused on tracking students' faces and gaze and do not track their postures, actions, and emotional state. However, it is the assessment of actions and emotional state that is crucial not only for the learning process itself, but also for the well-being of students, as they spend long periods of time at computers or other devices during distance learning, which has a great impact on both their physical health and stress levels. Currently, control over these indicators lies solely with teachers or even students themselves, who have to work through test materials and independent work on their own. An additional problem is the quality of processing and storage of students' personal data, as most systems require students to be identified using their identity documents and store full, unanonymised video of students' work on their servers. Based on the analysis of all these problems that impede the learning process and potentially affect students' health in the long run, this article presents additional functional requirements for modern automated online proctoring systems, including the need to analyse human actions to assess physical activity and monitor hygiene practices when using computers in the learning process, as well as requirements for maximum protection of students' personal data. A prototype of the main components of an automated online proctoring system that meets the proposed requirements has been developed.

Keywords: Distance learning; automated online proctoring systems; personal data protection; analysis of people's emotions; analysis of people's actions

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INTRODUCTION

Distance learning technologies are not a new field of application that began its development with the development and spread of computer technologies and the Internet. The problem of assessing students' behavior in the process of passing exams and completing individual work has always existed. Proctoring systems were proposed to solve this problem. Online proctoring systems are information systems designed to supervise the process of completing test or examination tasks and to monitor and evaluate student integrity. These systems mimic the role of a teacher by observing and evaluating student behavior. Initially, these were synchronous proctoring systems, where students were observed by people (teachers themselves or hired employees) [1]. To automate the process and reduce costly expenses, asynchronous proctoring systems were introduced [2, 3], where the entire process of passing test tasks was recorded and analysed by the teacher after the exam itself after the fact. However, the development of artificial intelligence methods and models has given hope for the automation of this process of assessing students' integrity. It is these information systems, automated online proctoring systems [2, 3], that this paper is devoted to.

LITERATURE REVIEW

There is a large number of automated online proctoring systems based on artificial intelligence [4, 5], [6, 7]. According to the peculiarities of these systems implementation and their use on various distance learning platforms, it was proposed to systemize them and divide them into three groups (Fig. 1, Table 1).

The first one is plug-ins. Plug-ins that can easily integrate into existing systems. These programs have access to limited functionality within the main platform: most run-in browsers and do not have access to the student's entire desktop. However, they have access to a microphone and camera.

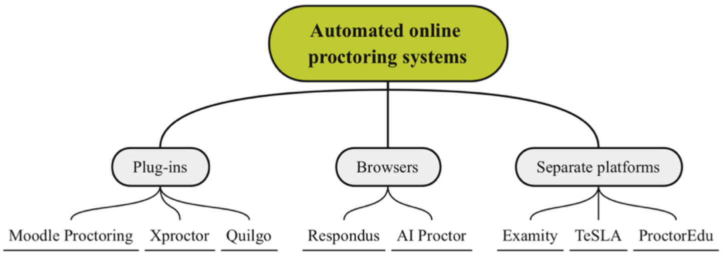

Fig. 1. **Example of classification of existing software products to support automated online proctoring**
Source: **compiled by the author**

Table 1. **An example of different automated online proctoring system implementations**

Name	Type	Computer vision module functionality
Moodle Proctoring	Plug-in for Moodle	Takes a photo of a student every 30 seconds and saves the photos in PNG format. Supports face recognition service (Amazon Rekognition) and its comparison with the student's profile photo
Xproctor	Plug-in. It can be configured with Moodle, Canvas, Blackboard, Desire2Learn. But it requires the installation of additional software to record video, audio, and other data	No. detailed info provided
Quilgo	Plug-in for Google Forms	Frame analysis, detection of eye movements, presence of a student at the workplace, and the presence of a third person
Respondus	Browser	Frame analysis, detection of eye movements, presence of a student at the workplace, and the presence of a third person
AI Proctor	Browser	Frame analysis, detection of eye movements, presence of a student at the workplace, and the presence of a third person
Examity	Separate platform	Detection of eye movements
TeSLA	Separate platform specialized in student’s identification functionality	Face recognition
ProctorEdu	Separate platform	Frame analysis, detection of eye movements, presence of a student at the workplace, and the presence of a third person

Source: **compiled by the author**

The second group are browsers. These software products perform exclusively proctoring system functionality. They work as “wrappers” or browsers for other software applications and web-resources. Their purpose is to control the applications and websites that a student can use. Such systems have access to the desktop, keyboard, microphone, and camera. These programs must be installed on students' computers.

An the lose ones are software products that do not integrate with other systems. These are the separate platforms. This causes a problem of synchronis-

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ing students' results with other distance learning systems that may be used by the educational institution and requires additional actions from both the teacher and the student.

Three AI-based proctoring systems, namely Quilgo, AI Proctor, and ProctorEdu, were tested to assess their performance. The systems demonstrated good performance in analyzing desktop and browser activity in all test cases. They also achieved satisfactory results in audio noise analysis, correctly identifying approximately 80 percent of the abnormal situations, although they sometimes gave a few false positives during the testing process. However, the computer vision module caused most of the difficulties. In fact, all the software products worked correctly in only 25-30 per cent of the test cases, with false negatives prevailing in the remaining cases. This means that while the systems demonstrated proficiency in analyzing desktop and browser activity, the computer vision module proved problematic. According to other developers and students themselves, other systems suffered from inadequate image processing and artificial intelligence algorithms and had difficulty working with students of different racial backgrounds [9, 10], [11, 12], [13, 26]. In addition, these systems generated numerous false positives due to overly strict requirements for student behavior (e.g., the requirement to look at the monitor at all times). As a result, for example, the developers of ProctorU decided to remove these problematic AI modules [8].

The same feedback and analysis of existing proctoring systems [9, 10] also raised many questions about the protection of students' personal data, as most platforms required students to show their personal documents for identification, and full records of students' work were stored without post-processing and additional depersonalization of data. This approach to working with personal data is, for example, a violation of the General Data Protection Regulation (GDPR).

THE PURPOSE OF THE ARTICLE

The purpose of this work is to improve and introduce the requirements for automatic online proctoring systems and develop a prototype of such a system.

MAIN PART. ARTIFICIAL INTELLIGENCE BASED PROCTORING SYSTEM REQUIREMENTS

As determined by the analysis of existing systems, the following fundamental problems were identified:

– the processing of personal data in proctoring systems is not transparent and does not meet the requirements of the GDPR. There are significant concerns about the inability to easily delete personal data and the lack of information about the quality and security of data storage;

– the functioning of pattern recognition modules in these systems is unpredictable;

– systems impose too strict requirements on student behavior, which leads to additional stress for students;

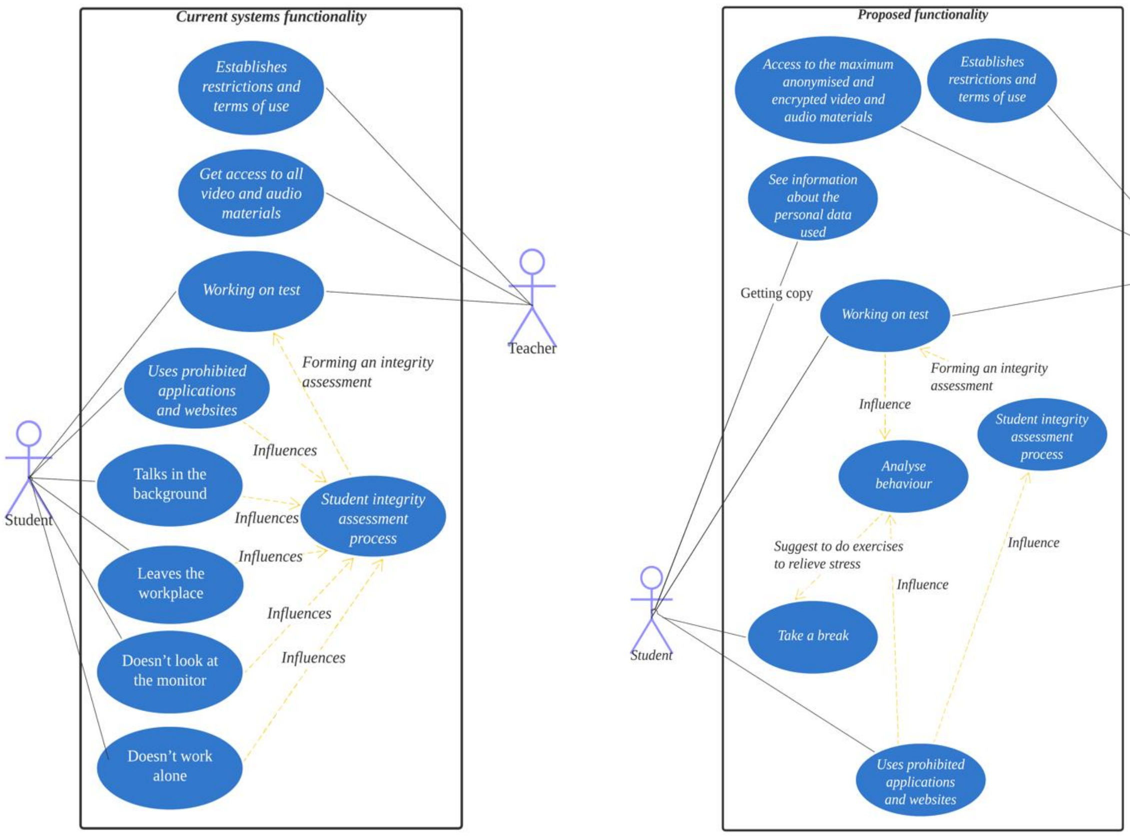
– there is no control over compliance with hygiene requirements for using computers and monitoring stress levels, which can have a detrimental effect on students' health.

The analysis showed that the systems under consideration both have excessive requirements for student behavior (for example, looking away from the monitor is considered an attempt to cheat) and a weak level of video sequence analysis (processing frames at an indefinite interval does not show the real picture of how a student works on an exam task). These problems, combined with the inflexibility of the types of test questions, have led experts to recommend reducing the time spent on test tasks and making them less difficult.

All of this has a negative impact on the level of knowledge gained. By addressing these issues and improving the transparency of data processing and storage, as well as adding control over students' stress levels and physical health, AI-based proctoring systems can be improved to provide a safer and more conducive learning environment.

It is proposed to add the functionality of tracking the emotional state and movements of the student to the existing functionality. Based on these changes, the functional requirements will include a comprehensive analysis of the student's work.

However, it's worth noting that, according to feedback from students themselves, tight control and excessive demands cause them to feel more stressed and afraid [10, 11], [12, 13], [14]. Excessive requirements for student behavior also misinform the teacher, as many systems falsely trigger minor movements of the student (if, of course, at that moment the system decides to process the frame from the camera data). Therefore, it is proposed to expand the existing requirements for student behavior in the direction of their mitigation and expand the functionality when using an automated online proctoring system (Fig. 2).



a b

Fig. 2. **Use-case diagram the existing and proposed automated online proctoring system: a – current functionality; b – suggested use-cases**
***Source:* compiled by the author**

Speaking about the improving the handling of students' personal data, the general data protection regulation includes the following basic ideas for handling personal data of software users:

– the user must be informed about what data the software product plans to collect about them. They should also receive clear information about the extent of data collection, the legal basis for processing personal data, the duration of data retention, data transfers to third parties or outside the EU, and any automatic decision-making based on algorithms;

– users have the right to withdraw their consent to data processing at any time, review their personal data and access information on how this data is processed;

– users have the right to receive copies of stored data, delete their data under certain conditions, challenge automated decisions based solely on algorithms, and lodge complaints with data protection authorities;

– algorithms should not use personal data of users, and the data itself should be stored securely;

– it must be ensured that data processing is not excessive and is only necessary. This means that only data that is absolutely necessary to fulfil certain purposes or tasks should be processed.

Based on these requirements, an algorithm for the system's work with students' personal data in the proctoring system was formed, which takes into account all of the above requirements (Fig. 3).

To depersonalize the data, it is also proposed to add noise to the audio files so that all the details of the conversations are not heard, and to blur the video sequence as much as possible in the places where the machine learning system is most likely to state the integrity of the student.

However, taking into account the fact that for some exams, all records of the student's work process must be presented, it is proposed to perform such post-processing at the request of the teacher when creating a test task.

Tracking and monitoring the emotional and physical state of the student. The emotional state of students is a very important part of the learning process. Researchers have shown a link between emotional state, awareness, and learning outcomes.

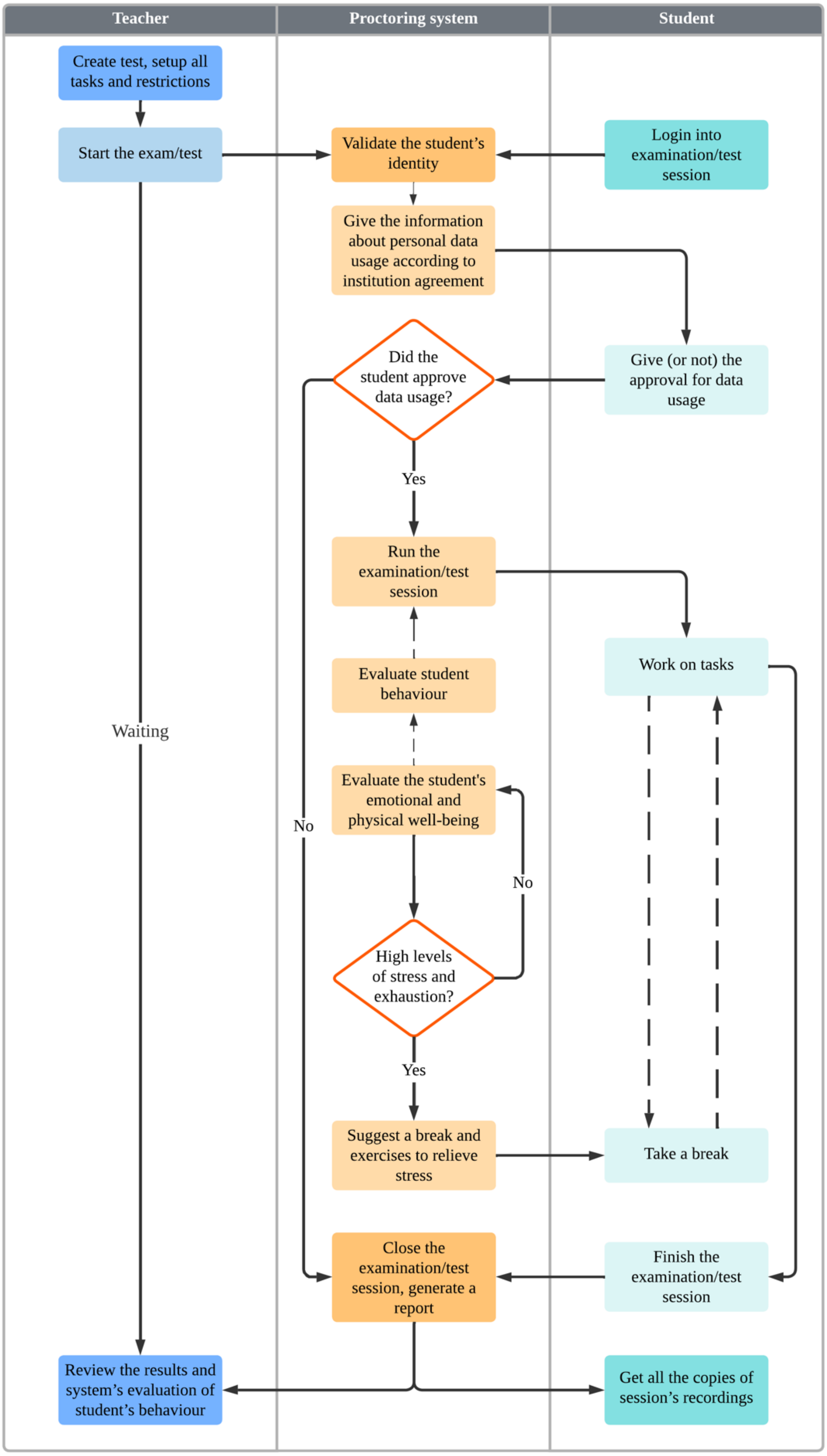


Fig. 3. **Swimlane diagram of actors and system communication**

Source: **compiled by the author**

When students are aware of their emotions and follow certain learning strategies, their academic performance improves in terms of motivation, engagement, and self-regulation. The situation is the same for teachers: when teachers are aware of their students' emotional state, their attitude and feedback become more effective and timelier [15].As it was mentioned earlier, modern implementations of proctoring systems are very strict in terms of compliance with test rules. And at the same time, in order to reduce the load on the system and save resources, they do not analyze the video in detail, but rather a set of frames every few seconds or even minutes. These strict requirements and the poor implementation of video sequence analysis (per-frame analysis does not give the full information about the emotions of a person in comparison to spatio-temporal analysis [17, 18], [19]) result in systems that are unable to adequately assess student behavior: they either miss violations of exam rules or react incorrectly to a student's blinking or yawning.

Also, as noted by the students themselves [20], awareness of such inadequate system behavior and the fact of constant monitoring of work causes additional stress for people. Working for long hours at a computer device also affects a person's stress level and physical health.

Given all of the above, it is proposed to add a comprehensive spatio-temporal analysis of student behavior to such systems, which will include both the processing of student actions and their emotions. This will allow timely breaks to restore the emotional state and help reduce the risk of developing health problems.

To describe and analyze students' emotions, it is proposed to use a system for coding facial (mimic) movements (Emotion Facial Action Coding System (EmFACS) [21] and Facial Action Coding System Affect Interpretation Dictionary (FACSAID) [22], which consider facial movements associated with emotions). This system describes in detail the activity units (AU) and descriptors associated with the human face. Movement units are independent of any specific interpretation and can be used to determine emotions (Table 2). The combination of several movement units defines a specific emotion (Table 3) [23]. This approach will help to provide a complex description and assessment of students' emotions, whereas the existing solutions focus solely on the direction of the gaze.

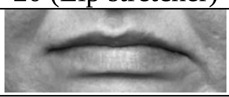
These classifications make it possible to structure the diversity of human emotions and describe the student's emotional state.

It should also be noted that there is a need to introduce improved datasets for training computer vision systems to recognize the emotions of people of different ancestry, racial background, and nationalities. It will help to avoid errors in recognizing people's faces and emotions. And in order to add a temporal component to the analysis of person's emotions, this dataset needs to contain video sequences and not just images.

The results of the module for analyzing the student's behavior and emotional state will be used both for the teacher's report and for the system for stabilizing the student's emotional state.

It is proposed to use markers of high stress to recommend a short break and perform distracting exercises: from movements [20] to the trivial "look out the window and rub your eyes" [24, 25].

Table 2. **An example of activity units**

AU code	4 (Brow Lowerer)	5 (Upper Lid Raiser)	6 (Cheek Raiser)
Example			
AU code	9 (Nose Wrinkler)	12 (Lip Corner Puller)	15 (Lip Corner Depressor)
Example			
AU code	20 (Lip stretcher)	23 (Lip Tightener)	26 (Jaw Drop)
Example			

Source: **compiled by the author**

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Table 3. **An example of combinations of activity units to describe emotions**

AU code	Happiness / Joy	Sadness	Anger
AU codes combinations	6 + 12	4 + 15	5 + 23
Example			
AU code	Anger	Surprise	Fear
AU codes combinations	4 + 23	5 + 26	5 + 20
Example			
AU code	Fear	Disgust/Hate	Disgust/Hate
AU codes combinations	4 + 26	9 + 26	9 + 15
Example			

Source: **compiled by the author**

IMPLEMENTATION

The analysis of existing solutions showed that the easiest to use systems were those that were integrated as plug-ins into modern distance learning systems.

For the prototype, it is proposed to develop an add-on for Google Forms and a Web application that will allow the teacher to view and configure the rules for conducting exams. Google Forms is an online platform that allows users to create and design questionnaires, surveys, and online quizzes.

As this is a plug-in that will run in a browser, the proctoring system will not have direct access to the student's desktop. This has been done for all browsers to ensure the safety of the users. However, there are API methods for getting information about browser tabs and whether or not the browser is in "focus" (used by user). This information would not be enough to fully control what happens on the desktop, but it minimizes the time and resources needed to install additional software.

It also minimizes potential problems with the system being developed, as the platform is limited to supported browser versions rather than operating system variants. This adds flexibility to the context of the computer environment in which both teacher and student work.

The system operates on cloud technology, enabling real-time collaboration and offers a range of powerful tools for customizing form questions according to specific requirements. This will make possible to minimize and facilitate the work of students in setting up their working device [26], facilitate the work of the teacher, who will not have to reraise the infrastructure of his classroom just for the sake of conducting tests and minimize the problems of supporting various operating systems.

It was proposed to use the adopted machine learning foundation model InternVideo [27], to implement complex analysis of human behavior in the machine learning module of the developed prototype (Fig. 4).

The final proposed architecture of the automated online proctoring system consists of three main parts (Fig. 5): a plug-in for User's computer, a cloud server, and databases storages.

learning module.

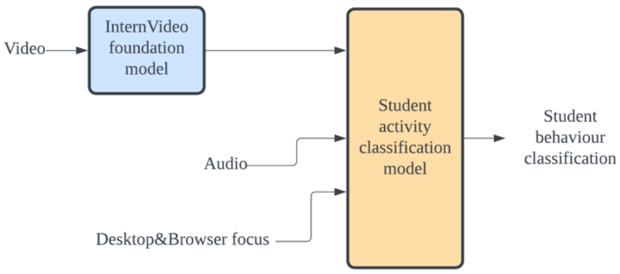

Fig. 4. **The architecture of the student productivity assessment model in proposed prototype**
***Source:* compiled by the authors**

The plug-in on the user's computer that consists of an interface, a data anonymizer, a camera interface, and a module for working with the cloud service via API.

The cloud server that will be used to analyze and evaluate students' performance in the process of taking a test or exam.

It includes: a metrics analyzer, a client request processing module (processing API), a user interface processing module, a database service module, as well as a user data processing module and an associated machine

The machine learning analyzes student behavior and provides a comprehensive assessment.

The EU and US databases storages will be separated to maximize support for potential users in different time zones, continuous replication [27, 28] and meeting the requirements for handling personal data of users in these parts of the world.

CONCLUSIONS

The paper proposes detailed and improved functional requirements for artificial intelligence based proctoring systems. The main components of an automated online proctoring system have been developed.

The analysis of the modern implementations and students' feedback showed the lack of "humanity" in them. Most of the systems pay attention on the direction of a person's gaze instead of the complex analyzing of their behavior. Moreover, these systems combine both strict unrealistic restrictions (for instance, person should look at monitor all the time of the test with the ability to look away for 30 seconds maximum) and a poor level of computer vision model implementation (analyzing random photos of the student in the different period of time, which does not provide spatio-temporal data analysis of person's behavior). Poor quality of machine learning methods implementation compensates strong behavioral restrictions and vice versa, but this workaround is pretty unstable. Such behavior analysis is unpredictable, and students understand that. But there were numerous situations where teacher took the side of these unreliable systems, and not the students' one. These situations cause additional stress for students and lower the quality of their work.

These systems should be more humane and should also take in the account the student's wellbeing. To obtain this goal it was proposed to use complex human-centric intelligent analysis of videos. At the same time, it was also suggested to make the behavioral requirements for students more flexible and less strict (for example, to remove the need to constantly look at the monitor). Proctoring systems based on AI should contain stress control module that will suggest students to perform exercises to relieve it if they need it.

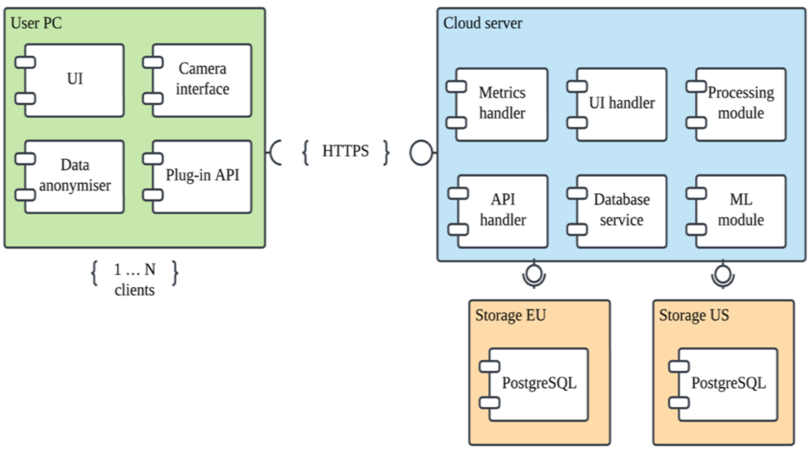

Fig. 5. **Diagram of components of the automated online proctoring system**
***Source:* compiled by the author**

Such control can be implemented in a more primitive way by setting a timer for the student's time in front of the monitor. However, our system proposes to monitor the emotional state of the student by analyzing emotions and movements from the data obtained from the webcam.

In terms of security in the use of personal information, it was proposed to anonymize students' data as much as possible after their identity has been confirmed and outside of suspicious situations that may indicate student dishonesty. It was also proposed to provide students with information about used personal data and conditions of its usage and deletion from the servers. Students will also have access to copies of all recorded data of their testing session so they could so that they can dispute the report of the automated online proctoring system if necessary.

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Розробка автоматизованої системи онлайн прокторингу

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АНОТАЦІЯ

Стрімкий розвиток технологій машинного навчання, збільшення доступності пристроїв і широкий доступ до Інтернету значно сприяли зростанню дистанційного навчання. Поряд із системами дистанційного навчання з'явилися системи прокторингу, які мають метою оцінювати роботу студентів, імітуючи роботу викладача. Однак, незважаючи на розвиток технологій обробки зображень і машинного навчання, сучасні системи прокторингу все ще мають обмежену функціональність: в деяких системах недостатньо задовільно були реалізовані методи та алгоритм комп’ютерного зору (хибні спрацьовування при роботі зі студентами різного походження, расової приналежності та національностей) та класифікації дій студентів (дуже жорсткі вимоги щодо поведінки студентів), що деякі програмні продукти навіть відмовились від застосування модулів, що використовують елементи штучного інтелекту. Також є проблемою, що сучасні системи переважно зосереджені на відстеженні виключно облич та погляду студентів і не відстежують їхні пози, дії та емоційний стан. Однак саме оцінка дій та емоційного стану має вирішальне значення не лише для самого навчального процесу, але й для благополуччя студентів, оскільки під час дистанційного навчання вони проводять тривалий час за комп'ютерами або іншими пристроями, що дуже сильно виплаває як на їх фізичного здоров’я, так і на рівень стресу. Наразі контроль цих показників лежить виключно на викладачах або навіть на самих студентах, яким доводиться самостійно опрацьовувати матеріали тестів та самостійних робіт. Додатковою проблемою є якість обробки та зберігання персональних даних студентів, бо більшість систем потребують ідентифікацію учня з використанням їх документів, що підтверджує особистість, а також зберігають повні неанонімізовані відео роботи учнів на своїх серверах. На основі аналізу усіх цих проблем, що перешкоджають навчальному процесу та потенційно ставлять під загрозу здоров'я учнів у довгостроковій перспективі, у цій статті були представлені додаткові функціональні вимоги до сучасних систем автоматизованого онлайн прокторингу, зокрема, необхідність аналізу дій людини для оцінки фізичної активності та моніторингу гігієнічних практик під час використання комп'ютерів у навчальному процесі, а також вимоги щодо максимального захисту особистих даних учнів. Розроблено прототип основних компонентів автоматизованої системи онлайн прокторингу, що відповідає запропонованим вимогам.

Ключові слова: Дистанційне навчання; системи автоматизованого онлайн прокторингу; захист особистих даних; аналіз емоцій людей; аналіз дій людей

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