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Applications of computer vision in examination proctoring

THESIS

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Abstract

In 2019, a disease called COVID-19 hit the whole world and with the appearance of this disease, a new era of distance learning has begun. Learning has moved to apps like Google Meet, Microsoft Teams, Zoom, Webex and messangers like Whatsapp, Telegram and etc. Almost all universities and schools changed their courses to reflect what is going on in the world now. With all of this going on, their grades and scores should be going down, but many students did better than the average. This is because there has never been a way to do a well-organized test online without using different methods for each student. To solve the problem at hand, we need a system that can help us figure out how students are cheating. When it comes to online tests, the use of proctoring procedures is a big problem for the research community. This work, shows to us how to make a full multi-model system using computer vision so that people don't have to be there during the inspection. We propose a system with many features that students can use during the test object identification, and estimating head posture using facial landmarks and face detection(is it the same student or another).

Аңдатпа

2019 жылы COVID-19 деп аталатын ауру бүкіл әлемді дүр сілкіндірді және аурудың пайда болуымен қашықтықтан оқытудың жаңа дәуірі басталды. Оқыту Google Meet, Microsoft Teams, Zoom, Webex және Whatsapp, Telegram және т.б. сияқты қосымшаларға көшті. Осының бәрін ескере отырып, олардың ұпайлары мен ұпайлары төмендеуі керек еді, бірақ көптеген студенттер орташа деңгейден жақсы оқыды. Себебі, әр оқушы үшін әртүрлі әдістерді қолданбай, жақсы ұйымдастырылған онлайн-тестті өткізудің ешқашан тәсілі болған емес. Бұл мәселені шешу үшін бізге студенттердің қалай алдағанын анықтауға көмектесетін жүйе қажет. Интернеттегі тесттер туралы айтатын болсақ, тексеру процедураларын қолдану зерттеу қауымдастығы үшін үлкен проблема болып табылады. Бұл жұмыс тексеру кезінде адамдар қатыспауы үшін компьютерлік көруді қолдана отырып, толыққанды көп модельді жүйені қалай құруға болатындығын көрсетеді. Біз студенттер тестіленетін нысанды анықтау кезінде және бет-әлпет пен бет-әлпетті тану арқылы бастың жағдайын бағалау кезінде қолдана алатын көптеген мүмкіндіктері бар жүйені ұсынамыз (бұл сол студент па немесе басқа біреу ма).

Аннотация

В 2019 году болезнь под названием COVID-19 поразила весь мир, и с появлением этой болезни началась новая эра дистанционного обучения. Обучение переместилось в такие приложения, как Google Meet, Microsoft Teams, Zoom, Webex и мессенджеры, такие как Whatsapp, Telegram и т.д. Почти все университеты и школы изменили свои курсы, чтобы отразить то, что сейчас происходит в мире. Учитывая все это, их оценки и баллы должны были снижаться, но многие ученики учились лучше, чем в среднем. Это связано с тем, что никогда не было способа провести хорошо организованный онлайн-тест без использования разных методов для каждого студента. Чтобы решить эту проблему, нам нужна система, которая поможет нам выяснить, как студенты обманывают. Когда дело доходит до онлайн-тестов, использование процедур проверки является большой проблемой для исследовательского сообщества. Эта работа показывает нам, как создать полноценную многомодульную систему с использованием компьютерного зрения, чтобы люди не должны были присутствовать во время осмотра. Мы предлагаем систему со многими функциями, которые учащиеся могут использовать во время идентификации тестируемого объекта и оценки положения головы с использованием лицевых ориентиров и распознавания лиц (это тот же студент или другой).

Acknowledgements

I want to say thank you to my supervisor Darmen Kariboz and Birzhan Moldagaliev for helping me in research and of course with my dissertation work. A lot of help was provided in the field of computer vision and in the study of algorithms. Since I'm new to this field, I had to learn a lot from my mentors.

I also want to thank the students of Suleyman Demirel University, namely the 1st year students, for their help in obtaining a database for my research. With their help, I have accumulated a huge database of photos with their faces.

I want to say a special thank you to Kamila Orynbekova, Askhat Aitimov, Shirali Kadyrov and other teachers of Suleyman Demirel University (SDU) for guiding, prompting, helping in my dissertation.

To my family

Contents

Nomenclature

SDU Suleyman Demirel University

1. Introduction

The increasing number of students enrolled in technical courses and programs has made administering tests a difficult undertaking. Overall, the process of preparing examinations, administering them, and, most importantly, analyzing the results has become extremely difficult and time-consuming. The recent pandemic scenario compounded this by forcing everyone to transition to an online format, which has its own set of drawbacks, including internet connectivity challenges, student perception, and, of course, plagiarism concerns.

Exams can be given in a variety of methods when taken online. Google Classroom, Moodle, Google Form, and Microsoft Teams, for example, all allow you to construct forms with a variety of question formats, including multiple-choice, fill-in-the-blanks, and open-ended questions. This may be adequate for a general purpose examination, but not for a coding or maths exam. And for conducting exams from a long distance, proctoring (or proctor system) was developed.

Proctoring

Many individuals in the community are unfamiliar with the term proctoring. There is a lack of clarity about how it operates and what it is in general. Meanwhile, proctoring is a technique that has the potential to accelerate the growth of distant education throughout the world.

Distance education allows you to obtain knowledge at a convenient time and at a low cost, but to confirm them, to obtain diplomas and certificates, the required certification is provided by proctoring, which allows you to conduct online exams without the involvement of an examiner (proctor), automatically calculating the degree of confidence in the results.

The American company Procter U started observing students for the first time in 2008: proctor followed students through webcams. Then they began to check the honesty of students after the exams, looking through the records for violations,

but this method still included the human factor, and the check was still carried out by a human. Proctor track took the next step by automating the supervision of examinees, but neither the students nor the teachers were yet ready for the machine to make a verdict on the presence or absence of dishonest behavior, and due to the large number of negative reviews, the company's reputation was spoiled. Proctor U took over the baton again, promising that there would be no inaccuracies in their product in the process of detecting violations[12].

To date, proctoring systems are represented by three modes of operation. The first and historically the earliest is the implementation of control by a person (proctor) in real time. He can usually watch nine students at the same time. His duties include confirming the identity of the examinee (as a rule, this is a visual verification of a person's face with a photo on an identity document that the student shows to the camera), monitoring students during the exam, can make comments to them, and also interrupt the exam if violations are detected: attempts to cheat or other dishonest behavior.

This option is usually called synchronous, since it assumes the simultaneous presence of students and the proctor on the network. Another option, in which the proctor looks at the record of the exam after it has been conducted and makes a verdict based on whether violations have been detected, is called asynchronous, since it does not involve the simultaneous presence of students and the proctor online.

Both options are working, allow you to conduct exams remotely and prevent substitution of the examinee. But they have a number of disadvantages:

- performance – depends on the number of proctors who can be online or view records of the progress of exams;
- time delay in the case of asynchronous proctoring, since it takes time to view videos;
- the cost of proctors' work is significantly high;
- difficulty in organizing the work of a large number of proctors;
- the human factor – the quality of the results depends on the attentiveness and honesty of the proctor.

Automation of proctoring allows you to eliminate these shortcomings, increase the speed of proctoring and reduce costs.

The second mode of proctoring is fully automatic, when the system independently, based on its algorithms, continuously authenticates the user and makes a decision about the presence or absence of violations and calculates the degree of confidence in the results. The system uses a webcam and a microphone to ensure that outsiders do not appear in the frame, that the examinee does not disappear from the frame, that he does not turn away, does not copy, does not switch the active window, and also that no one prompts him while behind the scenes.

This is the cheapest type of proctoring, but there are still ways to cheat the system or, conversely, get a comment from the system.

The combined proctoring mode, combining the two previous ones, is the most effective for online exams, but at the same time the most expensive. The program keeps a video recording, noting suspicious moments, which are then viewed by the proctor to make a final decision. But is proctoring really necessary? Or is it possible to do without it?

Many large companies, such as "Rostelecom", "Coca-Cola", "Pepsi" and others, give applicants for vacant positions a test task or ask them to take professional tests. With this approach, as is commonly believed, up to 85 percent of candidates are eliminated. The question is whether the results of the past candidates can be trusted. There are already sites on the Internet offering assistance with passing such tests for money, which means that the level of applicants who successfully "passed" the test can be completely unpredictable, not at all what companies expect [18]. The solution to the problem that has arisen is to implement proctoring systems when passing such tests, thereby excluding the passing of tests by other people.

Thus, proctoring can help not only in the field of distance education, but also in the selection and professional development of personnel. Proctoring systems are quite difficult to implement, so they are not part of online learning systems. As a rule, they are developed separately and then integrated into training or testing systems. The process of passing the exam by the examinees can be represented as follows: the examinee visits the online learning site; starts the exam; passes the exam (test, assignment, etc.); gets the result. That is, for the examinee, the exam process remains classic, and the proctoring system automatically connects

during the start of the exam and monitors during the exam. Graphically, this process can be represented as follows [19].

Let's take a closer look at each of the stages.

1. The exam that the student starts is automatically recorded in the proctoring system and linked to the examinee's account in the testing system (online learning). Since the examinee has already logged in to the testing system, authorization in the proctoring system occurs automatically.

2. Before the exam begins, the examinee's computer and network are automatically checked for compliance with the requirements. If the test is successful, then the examinee is not given any messages. When the system first accesses the webcam and microphone, the examinee is asked for permission to access the devices.

3. With the start of the exam, the process of monitoring the student is launched in the form of continuous data collection and analysis. If the system records uncritical violations of behavior, it can issue notifications to return the examinee's attention to passing the exam.

4. At the very beginning of the exam, the person authentication subsystem is trained using machine vision algorithms. After that, the system continues to monitor the examinee's face to track possible identity substitution during the exam. In addition, authentication by digital (keyboard) handwriting is also carried out. The subsystem is trained on the first hundred characters, and then tracks cardinal changes in digital handwriting. It works in those exams where the examinee needs to enter text.

5. After completing the training of the identity authentication subsystem, a photo of the examinee's face is saved and linked to the current exam.

6. After the exam is completed, its results become available within a few minutes

With the above scheme of integration of the proctoring system, the exam process for the examinee is no different from the usual online exam, except for the need to provide access to a webcam and microphone. Consider the subsystem for detecting dishonest behavior of the examinee during the exam. Throughout

the exam, the system automatically collects data from the webcam, microphone and actions on the computer. The data is analyzed, and based on them, an automatic assessment of confidence in the result is formed from 0% to 100%. At the same time, it is worth noting once again that the examinee does not need any specialized equipment to pass the exam. A webcam and microphone are enough, and most webcams are already equipped with a built-in microphone.

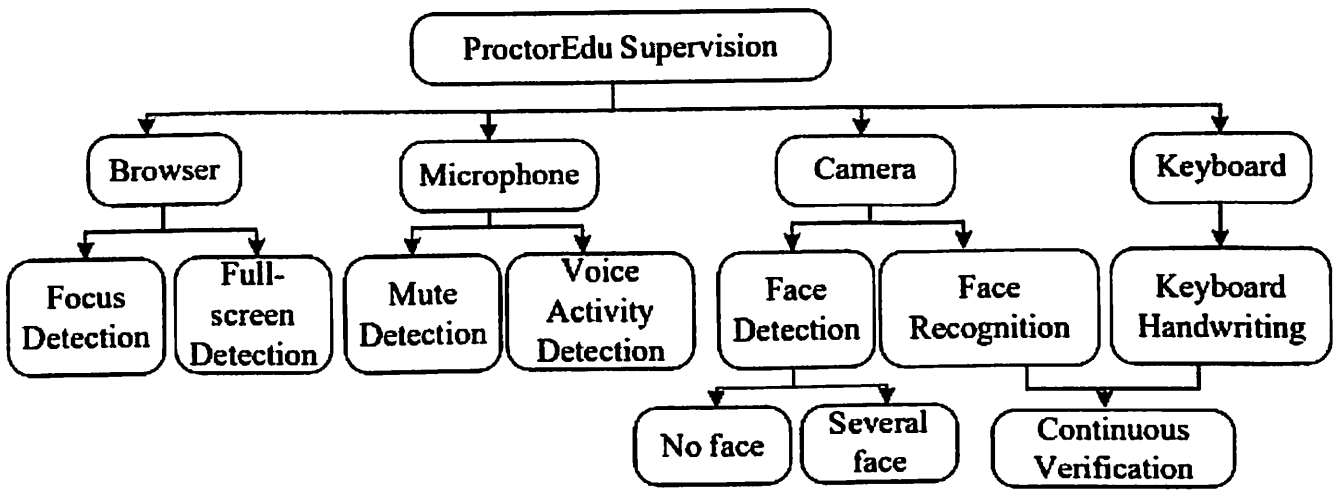

Figure 1.1: Subsystem for detecting dishonest behavior

What events are recorded during the exam:

- absence of the examinee's face in front of the camera;
- an outsider in front of the camera;
- unknown person in front of the camera;
- talk or noise;
- mute the microphone or low volume;
- new keyboard handwriting;
- the window with the exam page is not expanded to full screen;
- switch focus to another app or tab

The final score shows the normalized value of the most significant events during the exam recorded by the system. If the normalized value per minute exceeds a certain pre-set value, the system will record a violation.

As a result of the exam, the proctoring system will issue a confidence value for the result from 0 to 1 (or from 0% to 100%) and a photo of the examinee. The system will save a video recording of passing the exam with the noted violations.

Despite all the advantages and convenience of proctoring, today there are still those who are distrustful of proctoring. For example, someone is confused that an examiner is looking at them during the exam, and this prevents them from concentrating. In addition, there is always a chance that something will go wrong: the Internet connection will disappear, or the program or proctor incorrectly interprets the aversion of the gaze - a way to build thoughts, not a desire to peek. In addition, the Internet bandwidth for streaming video plays an important role, especially in remote small settlements where remote technologies are especially relevant.

Distance exams are a real way to demonstrate their knowledge, which, according to the order of the Ministry of Education, should be mastered by all universities in RK. Therefore, the debate about how necessary it is is no longer relevant. And the search for a solution to how to set up the proctoring process, on the contrary, is becoming increasingly important today.

Proctoring Software

The advantages of using remote proctoring software to proctor exams online are considerable. Several online remote proctoring service providers also give an application to assist you in supervising your examinations on a budget. However, as a user, you must be aware of which vendors are reliable and which test assessment systems are appropriate for your needs.[4] List of proctoring systems such as hackerrank, examus and other similar applications

- *Hackerrank*
- *Examus*

Hackerrank

HackerRank is one of the most prominent cloud-based programming platforms (www.hackerrank.com). It is developed further in industry [3]. For this reason, a number of systems have been developed, some of which even include automatic grading. These platforms are gaining a lot of traction, and they're being utilized a lot in computer programming classes. Maguire et al. also found that automatic machine evaluation increases students' self-confidence and self-sufficiency by requiring them to create all of the code without relying on others or outside resources. In order to pass the automatic test scenarios, the system also stimulates the learner to find the accurate and full answer.

Let's now talk about how the proctoring system itself works in hackerank:

Proctoring is a feature of HackerRank for Work that allows you to keep track of a candidate's attentiveness on the Test screen while they're taking the test. Recruiters can check their Candidates' genuineness and identify any suspicious behaviors or malpractices during the Test by having them proctored.

With the Candidates' permission, the Proctoring function automatically activates their webcam at the start of a Test and takes frequent photos of them until the Test is completed. Recruiters in HackerRank who are reviewing Candidates' Test results may also look at the recorded snapshots of their activity during the test and highlight any prohibited behaviors.

Before sending the Test email invites, you can activate Proctoring for a HackerRank Test. You may watch the webcam recorded snapshots of the Candidate's activity as the Candidate's Test advances in the Proctor tab of the Candidate's Summary page.

Let's look at how to activate Proctoring for a Test in HackerRank, as well as how Candidates react to these tests. Steps:

1. Log in to HackerRank for work and go to the top menu and select the Tests option.

2. Select the test for which you wish proctoring to be enabled.

3. Make sure you've included all of the essential questions, adjusted the parameters, and published the test.

4. Select the Test Access option from the left-hand panel on the Settings tab.

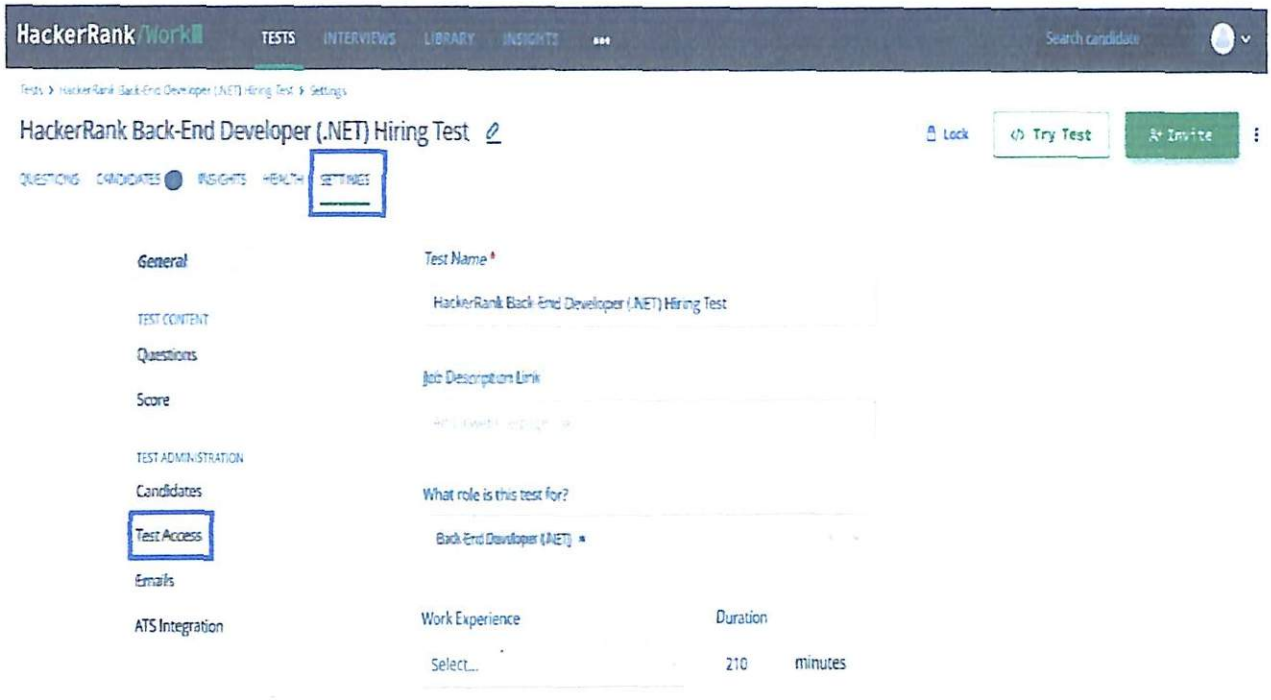

Figure 1.2: The tab for Test Settings

5. Scroll down to the proctoring area of the Test Access options.

6. HackerRank offers 4 types of proctoring during the test.

The Candidate's approval to turn on their camera to allow Proctoring will be obtained prior to the commencement of the Test. Once the Candidate's consent is obtained, the Proctoring function will automatically enable their webcam and capture frequent photos of the Candidate until the Test is completed.

Copy/Paste Tracking

All of your exams have Copy/Paste tracking enabled by default in the proctoring settings. You can see the pasted code in a candidate's test report if he or she pastes a copied code into the assessment. Additionally, if the applicant tries to copy and paste code from other sources, our plagiarism model will detect it. Candidates can also be warned of their copy-paste behavior via a caution popup, as seen above; however, we do not advocate displaying this warning within the product because it may encourage candidates to use other cheating methods (apart from copy-pasting). As a result, the prompt setting has been turned off by default in the settings. These options can be used in three different ways:

1. If you wish to collect candidates' copy-paste behaviour as part of the plagiarism model, leave the default parameters alone.

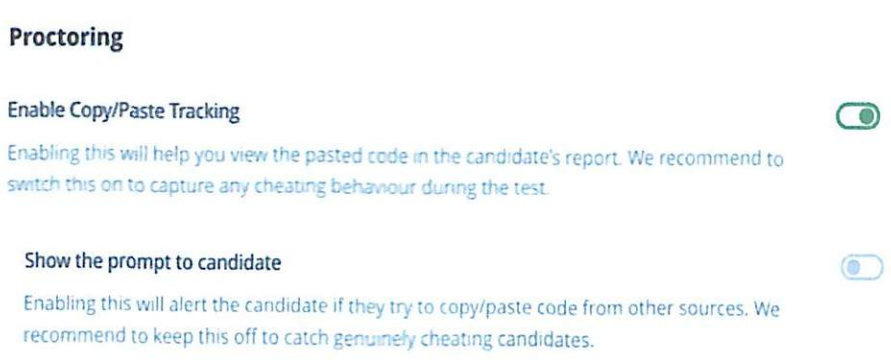

Figure 1.3: Access to Copy/Paste

2. If you don't want to collect a candidate's copy-paste activity / You're fine with candidates' copy-paste activity, turn off the copy-paste option.

3. If you want the copy-paste action to be captured as part of the plagiarism model but you also want to show the prompt to the candidates during the exam, turn on the prompt toggle.

Tab Proctoring

When you enable Tab Proctoring(see Figure 1.4), you may keep track of whether the applicant is flipping between tabs during the exam. This will prohibit applicants from engaging in any form of cheating while taking the test. If a candidate tries to open another tab on their browser while taking the exam, a warning notice will appear on their screen informing them that the test is being proctored, and if they continue to do so, the interviewer will be notified.

Details on proctoring can be seen in the candidate's report:

- To begin, open your test and choose the candidate's name.
- When the report is open, go to the top area and select the Timeline option.
- At the bottom of the timeline chart, click the Show entire event list option.
- This will open a detailed summary of the candidate's activity during the exam. You can see if the candidate pasted any code or switched between tabs during the test by looking report.

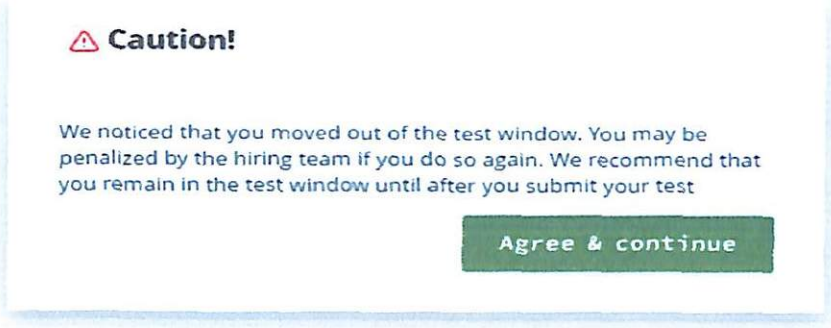

Figure 1.4: Agree with Tab

Photo Identification

Enabling picture identification allows you to keep track of whether or not the same applicant is taking the exam. When this option is enabled(see Figure 1.5), the system will take the candidate's photo before they begin the test. Before the commencement of the exam, the applicant will be contacted and a message will be sent to them, as well as a photo taken of them.

Previously, the test browser would have displayed a notice requesting the candidate to grant camera access.Candidates can then proceed to connect to the Test after clicking 'Enable webcam Access.'

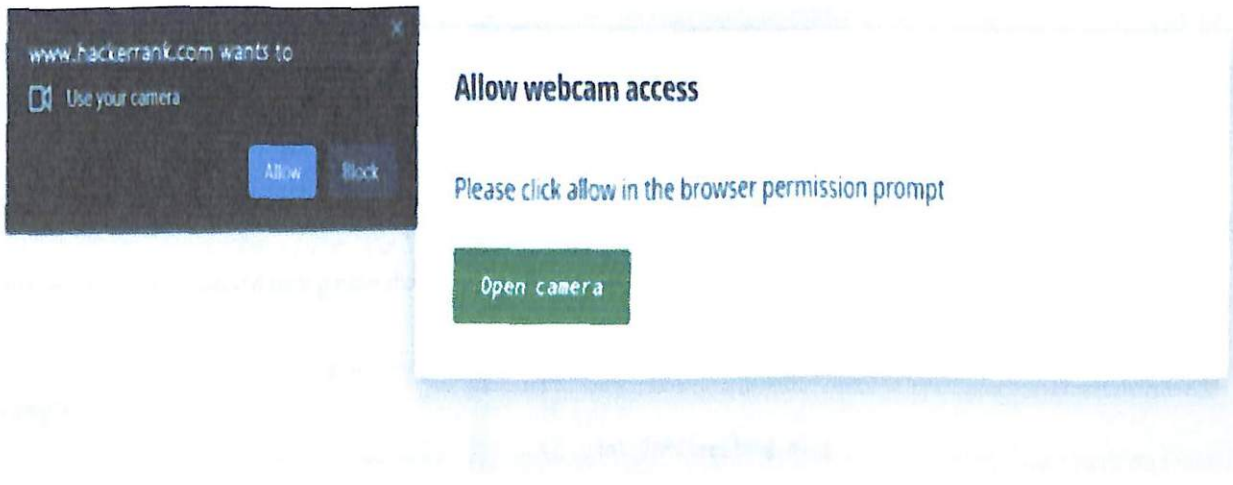

Figure 1.5: Enable to Camera Access

Proctoring

The camera is turned on from the start of the Test, and the Proctoring function collects and records frequent images of the Candidate. The camera collects and records a photo every minute for the length of the Test or until the Candidate

submits the Test. As a Candidate advances through a Test.

Examine the Proctoring Results:

- Log in to your HackerRank account for work. To begin, open your test and choose the candidate's name.
- Once you've finished the summary, go to the top section and select Proctor.

Before the Photo Identification exam, a snapshot(see Figure 1.6) was taken.Proctor snapshots collected at one-minute intervals during the test[6].

You can go through all of the photos using the scroll bar on the Proctor tab and make a note of any suspicious activities or malpractices by the Candidate.

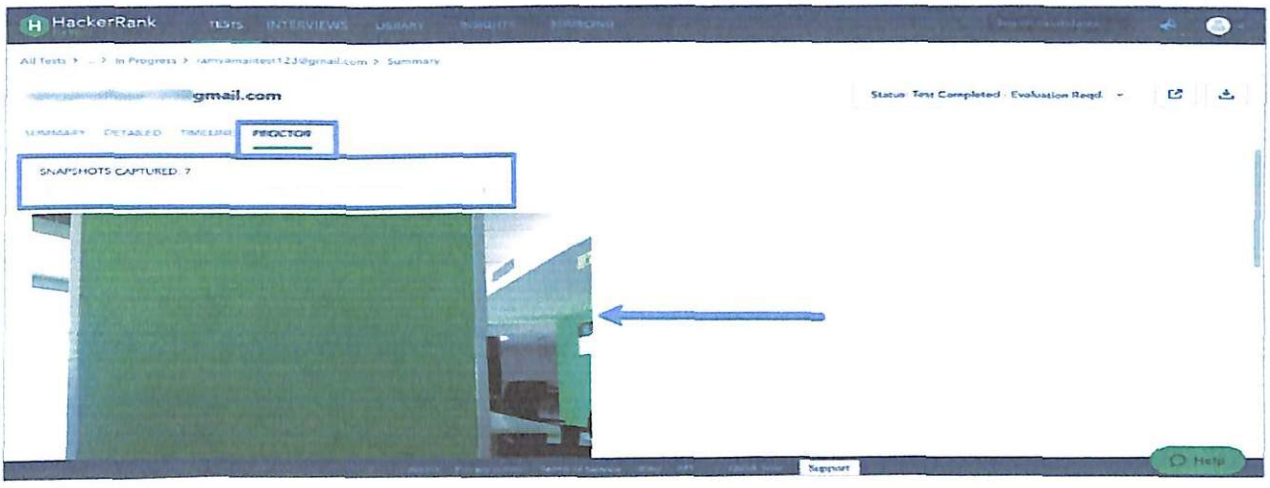

Figure 1.6: Snapshot

Hackerrank for Professor

Save time and keep track of hundreds of programming projects and assignments.

- Allow students to test and submit their code in a real-world setting.
- Streamline the process of creating, managing, and grading programming assignments.
- Students' performance is automatically graded and evaluated.
- Any contribution that is more than 70

Your recruiting organization may perform Hackerrank exams to examine candidates' coding and technical skills. These tests mostly consist of coding problems

of various difficulty in a variety of programming languages and frameworks. However, test setters may incorporate other sorts of questions, such as multiple-choice and diagramming, to check your knowledge in certain disciplines, based on the work needs.

The "Examus" proctoring system

Examus that was created with the help of the Skolkovo Innovation Center and the Foundation for Assistance to Small Innovative Enterprises in the Scientific and Technical Sphere. The main testing systems have already been combined with technology based on computer vision and artificial intelligence: National Platform "Open Education," Stepik, StartExam, Moodle, Webtutor, OpenedX, and Microsoft Teams. Examus may be incorporated into any distant learning management system.

Examus' key responsibilities include:

1. Face recognition and/or identification by an observer from a document with an image are used to determine the student's personality;
2. Creating a "digital footprint" in online courses (attended, engagement, and attention, as well as content reaction);
3. The Human behavior during internet activities is being observed and analyzed;
4. Examination of student behavior in relation to the guidelines for administering online assessments;
5. Detecting and resolving any efforts at bad faith, as well as the ability to interrupt the test if necessary;
6. Providing detailed information on the exam's content;
7. Monitoring students' "attendance" in the learning process (making sure they actually studied the suggested material);

And what is **advantages** of Examus proctoring system:

- Patented artificial intelligence technique
- Protection against passing a test without being proctored
- Proctoring oral examinations functionality
- Interfaces that are simple to use
- Examus team training and assistance
- An open API for integrating with a learning management system (LMS)
- Interface that is multilingual
- Installation on the customer's infrastructure (optional)
- Proctors with a lot of experience (optional)

There is an exam preparation control in Examus to gain access to the examination (see Figure 1.7). As a result, a webcam and microphone must be connected, a photo with a passport must be taken, and the user must agree to his webcam and desktop being streamed [5].

Figure 1.7: Exam preparation

It's difficult to tell if students are cheating or not on the Kahoot website and the TUIS (Moodle Platform). As a result, teachers must instruct pupils to turn on their cameras in order to monitor their emotions and where they are looking via a communication platform (MS Teams, Skype and etc.). When AI technology is in charge of all of these actions, Examus makes a difference. But Pedagogues-Methodologists are always welcome to make tests and watch

the progress of technology to learn how to solve new techniques for successful education in the future.

The evaluation was usually the same:

"Excellent" - granted for thorough and precise comprehension of the subject in a certain book. The written material should be free of errors. The student's speech must be logically supported and grammatically correct during oral questioning.

"Good" - denotes a thorough understanding of the subject with minor inaccuracies, omissions, or mistakes (no more than one or two).

"Satisfactory" - for understanding of a subject with evident gaps and errors that do not obstruct future study.

"Unsatisfactory" - for a lack of understanding of the subject, as well as a considerable number of mistakes in the spoken response or written work.

If examus and hackerank define proctorships through image and sound texts, let's find out how they do it or in other words, what they use. The first thing that comes to mind is that everything related to images (analysis, sorting, etc.) is related to computer vision. And what is computer vision, let's find out.

Computer Vision

It is widely known that with the help of vision, a person receives the greatest amount of information about surrounding objects, and without direct interaction with them. However, vision is given to people so naturally that few people think about how difficult the process of vision is. It is usually believed that the eye is a kind of camera that builds an image of the surrounding world, and this image alone is already enough to carry out the process of vision. But if the eye is just building an image, who is considering this image further and how is this process still carried out?

The actual complexity of vision was assessed only when attempts began to simulate it on a computer. The prospect of providing technical systems with vision was very attractive, because it would allow them to navigate the environment as easily as people. However, the first experiments revealed the enormous difficulties associated with endowing the machine with the ability to see. It turned out that images of the same object obtained in vivo are so different from each other that they are very difficult to recognize. It turned out to be not so easy to navigate in

space by images, since flat images do not explicitly contain information about the three-dimensional characteristics of surrounding objects and distances to them. Attempts to solve these problems have led to the emergence of a new field of knowledge – computer vision.

Computer vision is a fairly young (its origin can be attributed to the 1950s) and rapidly developing field of scientific and applied research, the main purpose of which is to build systems capable of "seeing", that is, extracting information about objects of the outside world from images, useful for further use within any application. At the same time, the processing of video information is carried out on universal or specialized computers.

The image coming to the input of the computer vision system is not necessarily the color image that is perceived by a person. Any spatially organized array of measurements of some physical quantities can act as an image. In particular, if the images are formed as the results of measuring the intensity of electromagnetic radiation in different directions, then they can be divided into classes:

- optical images;
- infrared images;
- uv images;
- x-ray images;
- images in the radio range.

According to the method of illumination, computer vision systems can be divided into passive ones – working with images obtained in natural lighting conditions, and active ones – using some radiation generator (for example, radar systems, laser rangefinders, systems with structured illumination, etc.). Another type of computer vision system activity may consist in automatically changing the shooting angle, focal length or any other lens parameters.

Thus, any spatially organized data arrays can be interpreted as images, which means that images as a source of information are very common. As the most frequently encountered classes of images belonging to various subject areas, we can name:

- indoor images;

- (ground) images taken outdoors;
- aerospace images;
- biomedical images;
- microscopic images;

The tasks of computer processing and image analysis open up broad prospects for automation of many spheres of human activity. The most obvious application is robot sensing. Indeed, it is difficult to imagine a robot capable of adapting to any changes in the situation without sensory organs. Adaptive robots have a variety of applications in manufacturing, assembling products, in everyday life (helping on the farm or sick people, for example, guide robots, or acting as pets), when exploring other planets or places dangerous to humans on Earth. Other applications include non-destructive quality control of manufactured products, navigation of unmanned aerial vehicles or cars, security and environmental monitoring systems, biometrics, smart photo and video cameras, image search systems in databases (both in home photo albums or the Internet, and in geoinformation systems), detection, recognition and tracking of targets and so on.

It should be noted that computer vision systems currently being developed are designed to solve specific tasks, are usually focused on one of the types of images listed above and work in limited subject areas.

At the same time, computer vision systems are significantly based on the specifics of the information being processed, and therefore this area has its own subject and research methods, that is, it is a separate branch of science. At the same time, it also intersects with such areas as computer graphics, image processing, psychology of perception, etc.

There are a number of terms that somehow relate to performing operations on images using computers:

1. computer vision (as well as technical vision, machine vision, robot vision);
2. image processing;
3. image analysis;
4. interpretation of the image;

5. understanding images;

6. iconics;

7. pattern recognition;

8. computer graphics;

9. cognitive graphics.

What is the reason for the complexity of computer vision and image analysis tasks? As already noted, images have great variability. Changing the shooting angle, lighting conditions, mutual movements of objects and their parts with partial freezing lead to complex transformations in pixel brightness with constant image content, which is called image variability. As a result, individual image points and even very large areas may not be sufficient to solve vision problems.

For example, the color of a particular object varies significantly depending on the lighting. A white sheet in dim light will be less bright than a dark gray sheet in bright light. Nevertheless, a person correctly determines colors regardless of lighting, which is called constancy of perception.

Lighting is often very complex: there may be several light sources (and not only point, but also extended), some objects may be in the shade, and some - in the light. Everything becomes even more complicated when the question arises of restoring three-dimensional information that is not explicitly contained in the image. Recognition of objects from images and semantic description of scenes is the most difficult task, not only due to the reasons for variability, but also a wide variety of objects and their complex internal structure and spatial relationships

Understanding Images

Computer vision systems often act as a component of a control or decision-making system designed to solve some problem in the real world, which is usually posed in terms of objects and situations. The restoration of three-dimensional shapes and movements of objects described in terms of a set of surfaces is insufficient.

Imagine, for example, a vehicle control system. Information about the three-dimensional structure of the scene is very useful, as it allows you to set the direction of possible movement and detect obstacles. However, the three-dimensional

characteristics of the curb or sidewalk may differ little from the roadway. Also, a pedestrian and a bush on the dividing strip will not be distinguished as obstacles. To make the right decisions, especially in emergency situations, it is extremely important to establish such a distinction.

Thus, computer vision systems may be required not only to restore the physical characteristics of objects, but also to construct a meaningful description of scenes. Semantic interpretation of images is called image understanding.

The problems of understanding images can range from recognizing or detecting single objects from their images to constructing a complete description of the scene within some knowledge representation system. Sometimes image understanding subsystems mean image processing systems included in artificial intelligence systems, but such a definition (even if it is considered correct) does not speak about the content side of the problem of understanding images.

It should also be noted that in the context of the problem of understanding images, the term "understanding" is usually used in the sense of procedural semantics: it is believed that the system "understands" the meaning of images or language statements if it can correctly act in accordance with them. For example, if the system can execute the command "bring the green pyramid located on the red cube", then it is assumed that the system understands the meaning of this statement, as well as understands the content of the images on the basis of which it executes the command [16].

Face Recognition

In computer science, facial recognition is basically the task of recognizing a person based on their facial image. This recognition algorithm has become very popular in the last two decades, mainly due to newly developed methods and the high quality of modern video cameras.

It is worth noting that face recognition is very different from other recognitions, since it has the purpose of finding faces (location and size) on the image and probably extract them for use by the facial recognition algorithm. And also when the images of faces have already been extracted, cropped, modified and usually converted to grayscale, the facial recognition algorithm is responsible for finding the characteristics that best describe the image. Facial recognition systems can operate mainly in two modes: face image verification or authentication: It basically compares the input face image with the face image associated with the

user who requires authentication. This is basically a one-to-one comparison [1].

Face identification or face recognition basically happens like this: the input face image is compared with all the face images from the dataset in order to find a user who matches that face. It's basically a one-to-many comparison.

There are various types of facial recognition algorithms, for example:

- own surfaces;
- local binary Histogram patterns (LBP);
- fishing faces;
- scale-invariant feature transformation (SIFT);
- – accelerated Reliable Functions (SURF).

Each method has its own approach to extracting information about the image and performing matching with the input image. However, the Eigenfaces and Fisherfaces methods have a similar approach, as well as the SIFT and SURF methods.

In conclusion to the examples given, it is worth saying that the scope of computer vision is quite extensive. Computer vision technologies have been actively used in household appliances recently. Currently, robot vacuum cleaners have been created that are able to clean rooms along a pre-programmed route and bypass obstacles, drones that can fly without human help. In the military industry, computer vision is used for the design of homing missiles, as well as for the design of self-guided robots for reconnaissance. In programs, computer vision is used when constructing 3D images from 2D (AutoCAD), as well as when editing images to improve their quality. This explains the fact that computer vision is quite a popular area in the IT field.

1.1 Motivation

The last 3 years have left a big mark all over the world, and especially in education. Tell me why, because all educational institutions had to switch from an offline format to an online one, and since this format was not practiced, much was done and decided during the learning process. The problem was that many students

found different ways of cheating in order to get a grade that they did not deserve (more precisely, without any effort, but just take it from someone).

Since I have been working as an assistant instructor at SDU for more than 2 years, and I also faced a similar problem. We used different systems, applications such as: Google Sheet, Moodle Classroom, Google Classroom, Examus system, Hackerrank platform,Moss system etc. But they had both pros and cons. And that's why I chose the topic for the thesis in order to create a proctoring system using computer vision and its recognition libraries that will do all the rough work and identify (show) cheating students during the exam.

1.2 Aims and Objectives

We already understand the meaning of the word proctoring, but why is it needed and what is its accuracy?

Testing is an easy way to test knowledge, get information about the level of academic performance and identify who understood the material and who could not assimilate what they passed. This is more convenient than written exams, as it allows you to simplify the verification and assessment of knowledge as much as possible. And when training takes place online, testing is fast and efficient. But all the work done in preparing the material may be in vain if the students managed to write off or use third-party "help".

How to conduct the most honest online testing? This is where proctoring comes to the rescue.

Today proctoring is actively used in many areas of eLearning, starting with HR specialists and ending with coaches and coaches. Besides, a proctor doesn't have to be a teacher. His main duty is to ensure that the test takers do not violate the rules of taking the test.

This process allows you to get the most objective results about students' knowledge.

What problems can arise when you use online proctoring. Let's discuss about these problems (more precisely, the problems that I met).

a) Number of students:

When the issues described above occur offline, that is, while you are studying at university, there are numerous issues that you are unaware of online. As I have

stated, there have been several instances of academic integrity violations when more than 900 participants take remote tests at the same time.

In fact, there are currently over 100,000 graduates, with 80 thousand passing the Unified National Test (UNT). As a result, approximately 55-65 thousand state grants are distributed, with at least 800 students in IT specialties entering Suleyman Demirel University (SDU) with a state grant each year. And, as you may be aware, when many students take tests at the same time, it is possible to make numerous errors, such as when a student uses a crib or when another student enters the room and takes the exam in place of a student. In fact, taking an exam through an interview is the most effective and right approach to take an exam since you can check if the student is truly learning and creating code at the moment. However, due to the high number of students nowadays, coding interviews are a challenging procedure; for example, at our institution (SDU), there were 897 students who learned the foundations of programming at the same time.

b) Online, i.e. remote:

When the issues described above occur offline, that is, while you are studying at university, there are numerous issues that you are unaware of online. As I have stated, there have been several instances of academic integrity violations when more than 900 participants take remote tests at the same time.

c) Academic dishonesty (plagiarism, the use of extra electronic devices, the passage of tests by someone other than a student, and so on):

Academic integrity violations are committed in a variety of ways [2]. Plagiarism, the use of extra technological devices, the passage of an exam by someone other than a student, and so on.

Types of violations of academic norms:

Ensuring academic integrity remains an urgent issue of the education system, regardless of the types and methods of control. According to the researchers of the problem of violation of academic norms, all universities publish individual criteria governing the process of assessing knowledge, highlighting the following most common types of violations

- **plagiarism**, that is, the inclusion of students in their own work of such elements of the works of another author or a team of authors as quotations,

paraphrased passages or any other elements without reference to the author in order to submit their work for evaluation, passing off borrowings as the results of their own efforts;

- **collusion**, that is, unauthorized cooperation of two or more students (or students and outsiders) in providing work that is submitted as a result of the work of a single student; or permission of a student (group of students) to include elements of his (their) work in work that is submitted for evaluation as a result of the efforts of another student;
- **falsification**, that is, the provision of work for evaluation, the data in which are either invented or knowingly falsely issued for the results of the student's own work;
- **replication**, that is, the repeated submission by a student of the same work more than once for evaluation in order to obtain credits, or academic credits;
- the use of notes ("cheat sheets") or technical means not allowed on the exam;
- illegal receipt of examination papers and/or answers before the exam;
- communicating or attempts to communicate with other students during the control;
- deliberately false impersonation of another person;
- provision of pre-completed work on the exam;
- copying of written works.

Of course, the problem of violating academic norms is aggravated if knowledge control is carried out online, which allows students to cooperate with each other, search for answers on the Internet, as well as resort to other types of violations [8].

d) Time:

Analyzing the final results takes a long time and is challenging. We have currently resolved all of these issues to the best of our ability. And, with the assistance of artificial intelligence, we're attempting to better it.

One of the most important problems was the loss of a very large amount of time. Since after the exams , in order to assess the student , such processes are done: A file with the results of the responses is downloaded. In this file there is a link to the individual result (more precisely with their photos). After checking the photo, there is an analysis of the exam itself. But it's a little easier here because they don't analyze the tests, but they have a definite/specific answer. But with questions related to coding or to write an answer to a certain question, with such forms of questions it is already difficult. It is necessary to go to each question and see how correctly (or how many percent) he /she answered this question. And since I said earlier there may be more than 500 or more such students, then in this case it will take more than 1 or more week for one teacher. For example, let's say that it takes at least 5 minutes to check 1 student, then it will take 2500 minutes for the whole class, which is about 42 hours, this is despite the fact that if the teacher does not get up to check all of them. But since I am an instructor myself and I myself have more than 700 students, it will take a few more days.

Now let's talk about how the tasks were distributed to solve these problems.

My goal is to create a system that will do things like:

1. Analyze the data obtained, check for plagiarism (with other students) or check the answers with those written on the Internet.

2. Running a certain script, he did all the rough work of the teacher (namely, grading). So that it doesn't take a certain amount of time.

3. For all the time that he/she wrote the exam, get their photo, and check it for recognition of his face (is it the same student)

What exactly needed to be done in the 3rd option, you need to get all the photos separately for each student, check for the excess of the photo, for the presence of extraneous things (smart watches, headphones, etc.)

1.3 Thesis Outline

The first chapter is Introduction chapter. It is this one that you are currently reading. It gives insight into the work done. There are also topics related to this thesis written here. And specifically, you can find out why, how they were used and how they are interconnected. In Chapter 2 we review proposed method over 2 years(or 4 semester). Here you may see all process step by step. Chapter 3 is

describing how I take or bring data from hackerrank platform. Also you can see in this chapter how big is it and what is in it. And in Conclusion chapter we conclude our conclusion. At the end. at 6 chapter you can find out what plans for the future I plan, or what other tasks will be completed in the future. Finally. you may see reference/bibliography to my thesis. SDU will stand for Suleyman Demirel University, Kaskelen.

2. Methods are Used

My thesis was separated into four sections for the most part:

- *Using Google Sheets to analyze exam results*
- *Creating a unique script (software) that loads photos automatically*
- *Computer vision concepts are used to detect plagiarism instances.*
- ***Machine learning algorithms are used to recognize faces.***

2.1 Using Google Sheets to analyze exam results

You may get the exam result in.XLS format from the HackerRank portal. We examine it by using Google Sheets to make the required adjustments, adding further features, and converting it to a more usable format. For instance, if numerous instructors are teaching the same topic, each of them is given unique opportunities, which means they can only enter their students' grades (see Figure 2.1).

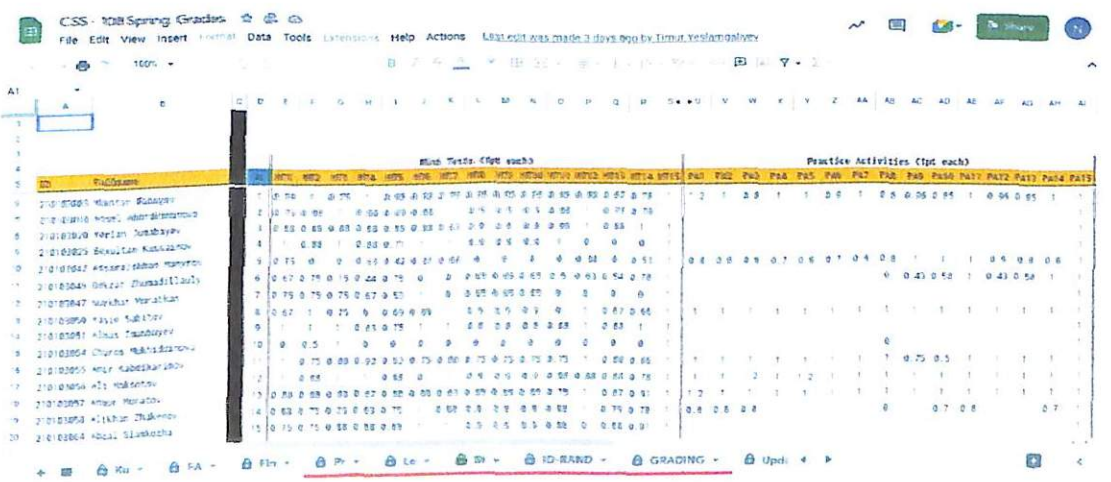

Figure 2.1: Grading sheet

In this sheet, it was possible to put an assessment after the analysis of the exam result was done. For each exam, a separate column is given for grades (For example: cookies, files, mini tests, etc.). Separately, through other sheets, you can connect with each other if there is a chance of cheating or plagiarism after checking the result. And summing up all the scores all the points that were taken from the Excel file, you can calculate the final, pre-final score.

Each sheet is designed for a specific teacher and student. Why is it created separately, so that each teacher can change and add grades only to his students.

We have figured out how we set grades for each student, and now let's look at where this data comes from

After completing the time and date of the exam, you can download the excel file where everything is written in detail (on the shelf).

Test reports from HackerRank give a complete insight of a Candidate's performance and test results. You may read full performance reports and download them in PDF or Excel formats after your Candidates have taken a test(see Figure 2.2). You can either share the downloaded reports with external assessors or recruiters, or simply keep a record of them.

Downloading the Test Reports: A Step-by-Step Guide

1. Go to the Tests tab and then choose the necessary Test.

2. Select the Candidates tab from the drop-down menu. In the Status column, you'll find a list of Candidates with their various Test statuses displayed.

3. Expand the Candidate Status category in the left pane of the Test Candidates menu and pick the Completed option. The Candidate entries who have attempted the Test and are awaiting Evaluation, Passed, or Failed the Test are listed in the right pane.

4. To get all of the Candidates' Test Reports, click Download and choose PDF or EXCEL.

5. To get particular Candidate reports, pick the appropriate Candidates, click Download, and then select PDF or EXCEL.

6. The method creates a folder containing a distinct PDF or a single EXCEL file for each Candidate, depending on your preference.

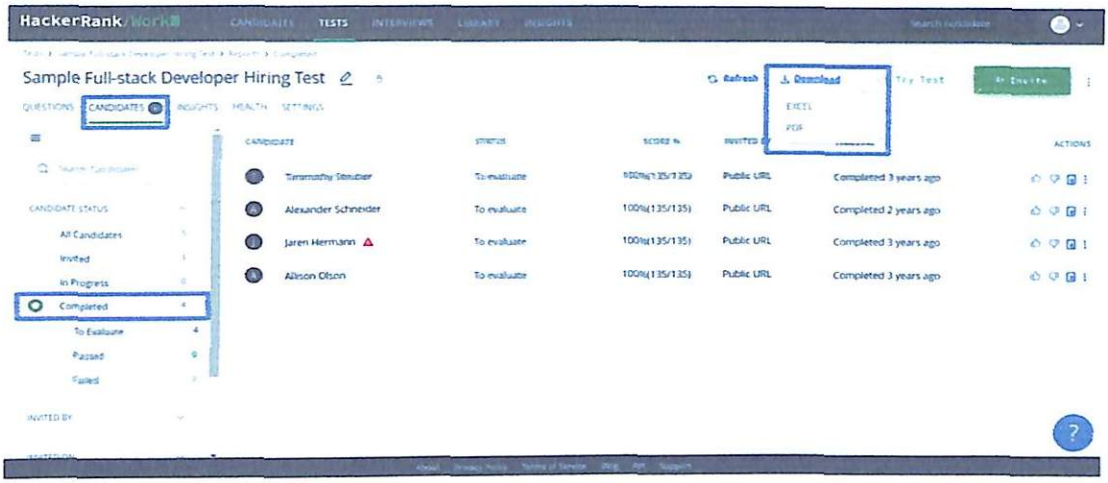

Figure 2.2: How to download exam report

This file contains data such as(see Figure 2.3):

- **Candidate name**. Full name of Student
- **Candidate email**. Email of Student
- **Invited by email**. Email of person who sent the link
- **Invited by name**. Name of person who sent the link
- **Test name**. Name of Test
- **Test Owner**. Name of person who created the Test
- **Attempt Starttime**. Students start time
- **Attempt Endtime**. Student end time
- **Attempt Count**. Number of attempts
- **Number Of Window Exits**. How many times he/she was out of window
- **Out Of Window Duration (seconds)**. Out of window duration in seconds
- **Detailed Report Url**. The url link for detailed information of their score
- **Max Score**. Maximum score
- **Score**. Exam result/score

- **Percentage Score**. Score in percentage
- **Network Disconnected Duration (seconds)**. Network disconnection duration in seconds
- **Attempt Plagiarism**. If any possible chance to be plagiarism
- **Candidate Detail Answer: Student Id**. Detail answer taken by student

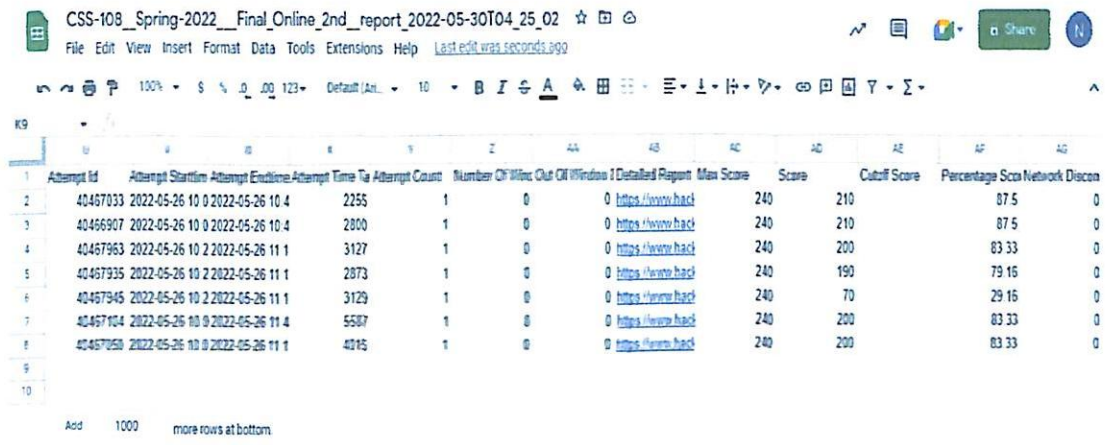

Figure 2.3: Hackerrank exam report

2.2 Creating a unique script

Every year the optimization process requires more and more technical skills. Among the current requirements for a specialist, it is often indicated that knowledge of a programming language, for example, Python, is necessary.

Any program must be started sometime, otherwise why write it at all? In interpreted languages, from writing code to launching is just one step. Nothing needs to be compiled into machine code, all the work is done by an interpreter, which just needs to submit a script for input — this is how programs in interpreted languages are often called, which are simple sequences of commands that the computer needs to execute. Often, languages that make it as easy as possible to write scripts (as they say, "scripting") and run them are called "scripting languages" or "scripting languages".

Python is a programming language that is great for developing stand—alone scripts. In order to achieve the desired result with the help of such a script, you need to write several tens or hundreds of lines of code. And after the job is done, you can just forget about the written code and move on to solving the next problem.

If, say, six months after a "one-time" script was written, someone asks its author about why this script fails, the author of the script may not know about it either. This happens due to the fact that documentation has not been written for such a script, due to the use of parameters hard-coded in the code, due to the fact that the script does not log anything during operation, and due to the lack of tests that would allow you to quickly understand the cause of the problem.

The script I created works this way, for its collection of data it needs an excel file and a path from where it will download all the photos of each student(see Figure 2.4).

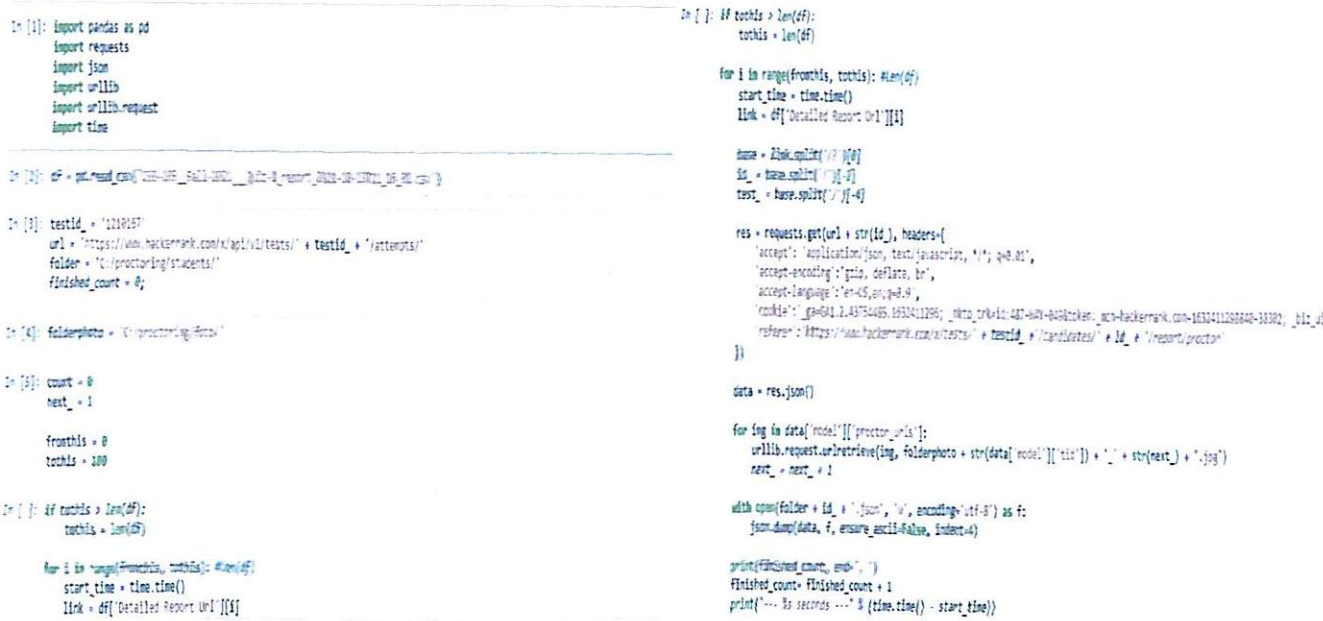

Figure 2.4: Python Script

Now let's analyze the entire code in part: On the first part of script we import libraries such as:

- Built on top of the Python programming language, *pandas* is a quick, powerful, versatile, and easy-to-use open source data analysis and manipulation tool.

- Python's *requests* module allows you to send HTTP requests. The response data from an HTTP request is returned as a Response Object (content, encoding, status, etc).

- To work with JSON data, Python comes with a built-in module named *json*.

In the second half of the script, we read the file using the 'read_csv' method from pandas library. This method reads all excel format files (XLSX,XLS,CSV).

Next, we create paths for folders where and how we will save certain photos and exam data of each student. We also create the startup time and how much time the script needs to load all the data. To do this, we imported the "time" library separately.

In the last part of the code, we run a program (cycle) that enters the "detailed information" column and, entering the "Proctoring" sector on the site, downloads from there all the photos available to a certain student. Ask how he enters the site, for this he uses the "request" library to allow and use the site for parsing. In

order not to load the site every time, it uses a "cookie" storage for downloading. And he saves the remaining photos in the way that we provided in advance (or rather "C:/proctoring/foto /") (see Figure 3.1) and thereby saves all his answers during the exam in a "json"(this is a kind of array) format. The bonus data that I added is a timeline for each student. After I ran the script and analyzed it, I noticed that on average it takes an average of 1 minute to collect information for each student.

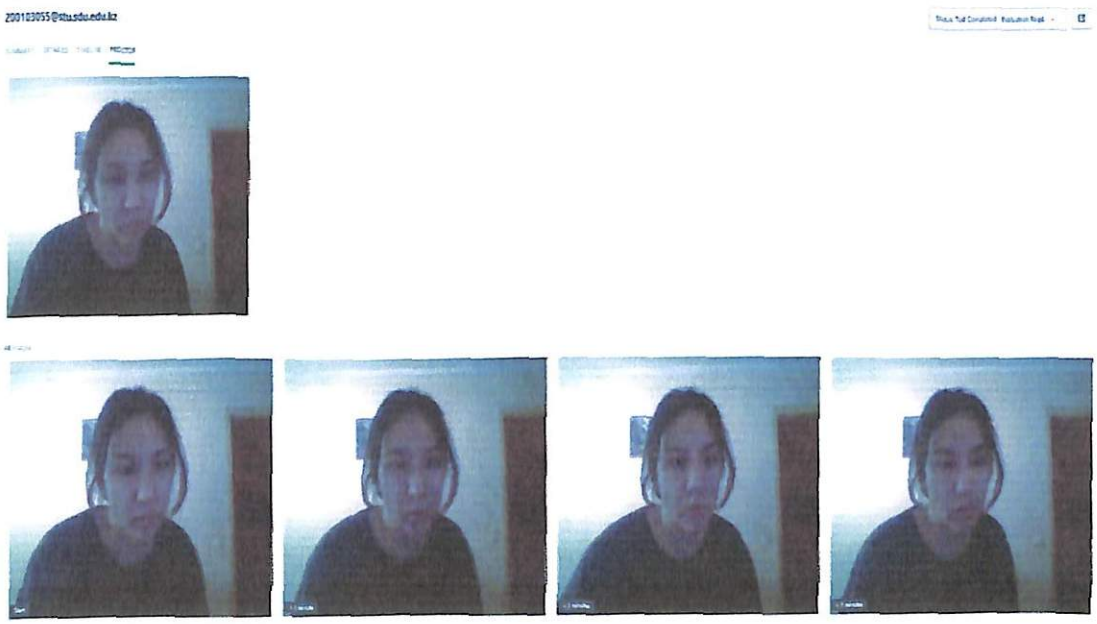

Figure 2.5: Images from Script

And at the end you can see a very large list of photos and the results of each of the participants. They are in other different ways.

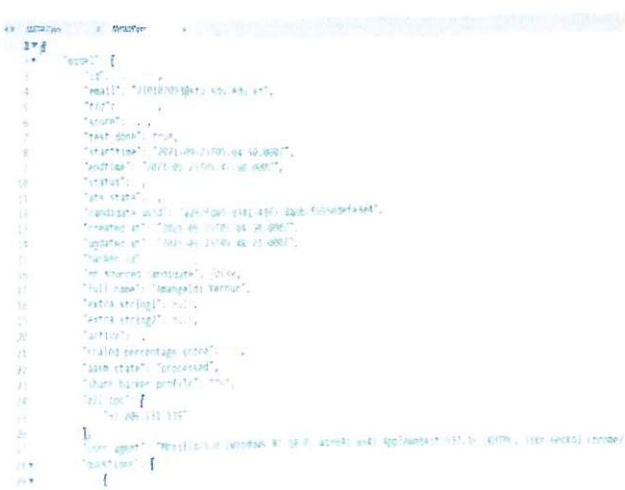

Figure 2.6: Information from Script

2.3 Computer vision concepts are used to detect plagiarism instances

Let's turn to one of the oldest and more popular face recognition algorithms: local binary histogram patterns (LBP).

Local Binary Pattern (LBP) is a simple but very efficient texture operator that marks the pixels of an image by the threshold value of the neighborhood of each pixel and treats the result as a binary number. It was first described in 1994 (LBP) and has since been recognized as a powerful texture classification tool. In addition, it has been found that combining LBP with histograms of the oriented gradient descriptor (HOG) significantly improves detection performance on some datasets. Using LBP in combination with histograms, it is possible to represent images of faces with a simple data vector. Since LBP is a visual descriptor, it can also be used for face recognition tasks.

Now, let's consider and study the steps of the algorithm.

1. Parameters: LBP uses 4 parameters.

A) Radius. The radius is used to construct a circular local binary pattern and represents the radius around the central pixel. It is usually equal to 1.

B) Neighbors. The number of sample points for constructing a circular local binary pattern. Keep in mind: the more sample points you include, the higher the computational cost. It is usually set to 8.

C) Grid X: The number of cells in the horizontal direction. The more cells, the thinner the grid, the higher the dimension of the resulting feature vector. It is usually set to 8.

D) Grid Y: The number of cells in the vertical direction. The more cells, the thinner the grid, the higher the dimension of the resulting feature vector. It is usually set to 8.

2. Learning the algorithm: First, we need to train the algorithm. To do this, we need to use a dataset with images of the faces of the people we want to know. We also need to set an identifier (it can be a number or a person's name) for each image, so the algorithm will use this information to recognize the input image and give you the output. Images of the same person must have the same ID. With the training set already built, let's look at the computational steps of LBP.

3. Applying the LBP operation: The first computational step of LBPH is to

create an intermediate image that better describes the original image, highlighting the characteristics of the face. To do this, the algorithm uses the concept of a sliding window based on the parameters of the radius and neighbors.

4. Histogram Extraction: Now, using the image generated in the last step, we can use the x and y grid parameters to split the image into multiple grids.

Then we need to combine each histogram to create a new and larger histogram. Suppose we have 8x8 grids, we will have 8x8x256=16384 positions in the final histogram. The resulting histogram represents the image characteristics of the original image.

5. Performing face recognition: At this stage, the algorithm is already trained. Each created histogram is used to represent each image from the training dataset. So, given the input image, we perform the steps for this new image again and create a histogram.

So to find an image matching the input image, we just need to compare two histograms and return the image with the nearest histogram. We can use different approaches to compare histograms (calculate the distance between two histograms), for example: Euclidean distance [3], chi-squared, absolute value, etc.

Thus, at the output of the algorithm we get the ID of the image with the nearest histogram. The algorithm should also return the calculated distance, which can be used as a "confidence" measurement. Then we can use the threshold to automatically assess whether the algorithm has correctly recognized the image. It can be assumed that the algorithm has successfully recognized if the confidence probability is below a certain threshold [13].

At the end, we can conclude that LBPH is one of the simplest face recognition algorithms. It can represent local objects in images. With it, you can get excellent results, (mostly in a controlled environment). It is resistant to monotonous gray scale transformations. This is provided thanks to the OpenCV library (an open source library for computer vision).

2.4 Machine learning algorithms are used to recognize faces.

Computer vision methods are capable of processing input information of any format: two-dimensional and three-dimensional images, video, audio. An example of sound processing technology using machine learning is the Sounds service from Mail.Ru within the framework of the Mail Could Solutions platform. Video in the process of processing by computer vision services is converted into an array of frames, each of which is processed separately. An example of a video processing service using computer vision is the cloud service from Google Could Videos Intelligent API. This service allows you to index videos, search for a specific object in the video or view all its occurrences. The Microsoft Azure software product from the company of the same name can serve as a service using machine learning that processes images. The implementation of computer vision methods is focused on the resources of the executing machine, the required performance and the scope of application. Computer vision systems include a number of common functions [20].

A. Getting objects. These can be 2D or 3D images; sound; video.

B. Pre-treatment. Before applying algorithms, objects must be processed. Input data processing includes the following methods: remove noise, adjust the brightness and contrast for images to successfully detect the object, check the correctness of loading the object, set the maximum volume for audio files, scaling images to improve their quality.

C. Highlighting details. Details of various levels of complexity are highlighted from the input file. For example, for an image, a structure is highlighted, refers to a structure, shape, or movement.

D. Detection and segmentation. At this stage of processing, the selected parts are analyzed and a decision is made which of them are of interest for further processing. An example is the selection of a group of points or the segmentation of an object in an image.

E. High-level processing. At the final stage of processing, a list is formed containing data about the objects found. For example, for images, this list may contain a set of points or a section of the image in which the object is presumably located.

3. Preparation of Dataset

3.1 Dataset Collection

I have already talked about the importance of the Data Preparation stage, the result of which is a processed set of purified data suitable for processing by Machine Learning algorithms. Such a sample, called a dataset, is needed to train the Machine Learning model in order to train the system and then use it to solve real problems. However, since it is necessary to evaluate the quality of the model in the learning process, there are several types of samples. In this article, we will tell you what a dataset consists of, what datasets are and how to form them.

A dataset for machine learning is processed and structured information in tabular form. The rows of such a table are called objects, and the columns are called attributes. There are 2 types of signs

independent predictor variables;

dependent variables are target features that are calculated based on one or more predictors.

A feature description is typical for classification problems when there is a sample – a finite set of objects for which it is known which classes they belong to. The class affiliation of the remaining objects is unknown. In the process of machine learning, a model is built that can classify an arbitrary object from the original set [10]. The practical meaning of classification tasks is to predict possible outcomes based on a set of input variables, for example, diagnosis of diseases, preliminary assessment of the effectiveness of mineral deposits, credit scoring, speech recognition, prediction of customer churn Rate, etc.

If you once studied at the universities of the Republic of Kazakhstan, then you know that each academic year has 2 semesters (this is not taking into account the summer). And in each semester you must choose at least 4 main (by profession)

lessons. And since this lesson is the main one, I also teach one of these lessons, the number of students who chose my lesson is also significantly large. We do 4 exams per semester (3 quizzes and one final exam). If you look at the results of the last 2 years, then I can say with confidence that at least 700 students attended each semester. And if you calculate it this way, you can collect colossal data, namely 2 (semesters)*4(number of exams)*700(number of students) = 5600 photos every year(see Figure 3.1). And this database provides a huge opportunity to train the algorithms module with machine learning.

Figure 3.1: Images from Script

3.2 Dataset Wrangling

With the development of information technologies, a huge amount of heterogeneous data is accumulated and processed in the world. Terms such as "Big Data" and "data processing", which gained great importance in the late 2000s, not only firmly entered our world, but also became extremely popular. The purpose of this work is to substantiate the need for data purification, as well as to consider some modern approaches directly to the data purification process.

"Big Data" is a set of methods and approaches for processing portions of data of varying complexity (structured, for example, in relational databases, and unstructured, for example, output data obtained by parsing html pages) in order to identify information suitable for forecasting, or to identify hidden trends and facts necessary for effective development of the company.

A data warehouse is usually a system from a database, a framework and a metadata database, which is a unified space that allows you to combine and accumulate information from various data sources (different DBMS, TRM, files on a local computer, ERP and CRM systems), for centralization and accumulation of information in order to obtain reports, facts for decision–making solutions, or forecasting. The key features of the data warehouse are continuous routine loading of information from sources and scalability.

Metadata is data about data that contains information about the work of tasks in the data warehouse. For example, the launch time and the result of uploading data to the report.

"Dirty" data

Due to the fact that the amount of information in the data warehouse is continuously increasing, the amount of unnecessary data that needs to be cleaned increases, so as not to expose expensive computing resources to unnecessary work and not clutter up physical media. If we assume that errors and inconsistencies in the data occupy a certain constant share of the total, and even take into account that with the improvement of technologies and methods of data collection, this percentage becomes smaller over time, the amount of "bad" data at the output is still rapidly increasing.

At the beginning of the 21st century, the volume of corporate data warehouses began to increase according to an exponential law, which confirms the relevance

of the current problem and the need for timely cleaning of large structured and unstructured volumes of data.

Another important feature of the modern world is the multitude of heterogeneous data sources. Any large and long-established corporation has several databases related to different types of activities. For example, data from html pages, files on a local computer, corporate databases of a narrow focus, resource planning information systems can be used as separate data sources. The data may have different representations and structures, and sometimes it may even be inconsistent, for example, due to an input error in one of the internal systems that is associated with the data warehouse. As a result of the human factor, the original record does not carry a semantic load (either part of the attributes is lost, or the record cannot be read). Such a record is called "lost" (English orphaned – orphan). Integration of multiple sources (repositories, integrated database systems, global Internet information systems) this is always a point of vulnerability, as the data may be inconsistent, which creates an additional need for data cleaning and transformation.

Tools and methods for data cleaning.

To identify the types of errors and inconsistencies to be deleted, a detailed analysis of the data is required. There are many tools with different functionality designed to support such tasks. PURE INTEGRATE (Oracle) contains tools for extracting and converting names and addresses into separate standard elements, checking the validity of street names, cities and indexes, along with matching capabilities based on cleaned data; MASTERMERGE (PitneyBowes) – a tool for identifying and removing duplicates. In practice, there is often quite a large amount of cleaning and transformation work.

To identify the types of errors and inconsistencies to be deleted, a detailed analysis of the data is required. There are many tools with different functionality designed to support such tasks. PURE INTEGRATE (Oracle) contains tools for extracting and converting names and addresses into separate standard elements, checking the validity of street names, cities and indexes, along with matching capabilities based on cleaned data; MASTERMERGE (PitneyBowes) – a tool for identifying and removing duplicates. In practice, often a fairly large amount of cleaning and conversion work has to be done manually or by low-level programs, which are often difficult to write, use and maintain. It is interesting to note

that at the moment, especially in countries with a relatively low cost of labor (including fully qualified), like Russia, it is often much more profitable to carry out manual cleaning. On the one hand, the human factor, especially when performing monotonous work, will be a very serious risk, but on the other hand, a person, unlike software tools, including artificial intelligence and self-learning systems, can find and correct non-trivial errors and inconsistencies. Software tools still need to be developed and man-resources spent on it.

As practice shows, before applying any method of data cleaning, it is advisable and optimal to find a balance between the availability of dirty data and the cost and or time required to clean them. Each data cleaning method must meet a number of criteria:

1. It is necessary that it identifies and removes all major inconsistencies and errors not only in individual data sources, but also when integrating heterogeneous sources.

2. The method should be supported by certain tools in order to reduce the amount of manual verification and programming, and be flexible in terms of working with additional sources. The use of the utility must be documented and be in the "transparent" box state.

3. The use of scripts or utilities that perform data cleaning functions should not interfere with the work of threads or block routine processes in the data warehouse.

4. Mapping functions for cleaning and other data transformations should be defined declaratively and suitable for use in other data sources and in query processing.

Stages of data cleaning

Consider and systematize on the basis of: data cleaning steps:

1. Data analysis. A detailed analysis of the data is necessary to identify the types of errors and inconsistencies to be deleted. Here you can use both manual verification of data or their templates, and special programs to obtain metadata about data properties and identify quality problems.

2. Definition of the order and rules of data transformation. Depending on the number of data sources, the degree of their heterogeneity and contamination, the data may require quite extensive transformation and purification. The first steps of cleaning can clarify or change the description of the problems of individual data

sources, as well as prepare data for integration. Further steps should be aimed at integrating the schema/data and eliminating the problems of multiple elements, for example, duplicates. For Repositories, in the process of defining ETL, control methods and the data flow to be transformed and cleaned must be defined.

3. Confirmation. At this stage, the correctness and effectiveness of the conversion process and definitions are determined. This is done by testing and evaluating, for example, on an example or on a copy of the source data, to find out whether it is necessary to improve these definitions in some way. When analyzing, designing and confirming, many iterations may be required, for example, due to the fact that some errors become noticeable only after certain transformations are carried out.

4. Transformations. At this stage, transformations are performed either in the ETL process to load and update the Data Warehouse, or when responding to queries from multiple sources.

5. Counterflow of cleared data. After the errors of an individual source are removed, the contaminated data in the original sources should be replaced with cleaned ones, so that the improved data also gets into legacy applications and does not require additional cleaning later on when extracted. For repositories, the cleared data is located in the data storage area.

Such a transformation process requires large amounts of metadata (schemas, schema-level data characteristics, process definitions, etc.). For consistency, flexibility and ease of use in other cases, this metadata should be stored in a DBMS-based repository.

Figure 3.2: Wrangled dataset

4. Methods of ML

5 main methods of image processing that perform face recognition are considered, and these methods are compared. The list of considered methods is given below.HP

- Convolutional Neural Network (CNN)
- Random Forest
- Hiddent Markov models(CMM, HMM)
- Principal component analysis
- Active Appearance Models, AAM

The data of computer vision methods is presented below, including a description of the methods where their "strengths" and "weaknesses" are identified, as well as the optimal method of face recognition identified as a result of comparison.

4.1 Convolutional Neural Network (CNN)

TThe interest in face recognition and recognition processes has always been significant, especially in connection with the ever-increasing practical needs: security systems, credit card verification, forensic examination, teleconferences, etc. Despite the clarity of the everyday fact that a person identifies people's faces well, it is not at all obvious how to teach this to a computer, including how to decode and store digital images of faces. One of the best solutions to this problem may be the use of neural networks.

Various machine learning algorithms are used to create a neural network. Having done an empirical study of the most popular algorithms, the most optimal of them were selected.

To solve the tasks , the following main steps can be distinguished:

1. Search for all the faces in the photo: it is necessary in order to highlight the area of the image that is transmitted for further processing. A histogram of directional gradients is used for this purpose(Histogram of Oriented Gradients - HOG).

According to this algorithm, the image is made in black and white, because color data is not needed to search for faces. In the loop, each pixel and its neighbors are viewed, with the goal of finding out how dark the current pixel is compared to the surrounding ones. Then an arrow is added showing in which direction the image is getting darker. After performing this procedure for each individual pixel of the image, each pixel is replaced by an arrow. These arrows are called gradients, and they show the direction from light pixels to dark pixels throughout the image. If you use dark and light images of the same person, the pixels will have different brightness indicators, but when considering the direction of brightness changes, the same picture is obtained regardless of the brightness of the original image. To save resources and get rid of redundant information, the image is divided into blocks of 16x16 pixels. Then replace this square in the image with arrows pointing in the same direction as the majority.

Eventually, the original image is transformed so that the basic structure of the face is clearly visible. To find a face in a HOG image, it is necessary to find the part of the image that is most similar to the well-known HOG drawing obtained from many other faces during training.

2. Face location: in order to make it easier for the computer to work with rotated faces, it is necessary to transform each image so that the eyes and lips are always in a specific place. To solve this problem, an algorithm for evaluating facial landmarks (face landmark estimation) is used. The basic idea is that there are 68 special points (called landmarks) that exist on each face – the upper part of the chin, the outer point of each eye, the inner point of each eyebrow, etc. Then a machine learning algorithm is trained to find these 68 singular points on any face.

When the eyes and mouth are detected in the image, it can be rotated, scaled and shifted so that the eyes and mouth are centered as best as possible. For centering, only basic image transformations are used, such as rotation and scaling, which preserve parallel lines - muffin transformations.

This method of image transformation is based on the following principle: for each point of the final image, a fixed set of points of the original is taken and interpolated in accordance with their mutual position. Affine transformation is the most general one-to-one mapping of a plane to a plane, in which straight lines and the ratio of the lengths of segments lying on one straight line are preserved. After this transformation, the face is centered at approximately the same position in the image, which makes the next step more accurate.

3. Face encoding: the face image obtained after the first steps must be "encoded" in a unique way, since comparing the resulting image with all previous ones is an irrational approach in the presence of a large database of images. So we need a way to take several basic measurements from each face, which we could compare with the closest known measurements and find the most similar face. In 1960, Woodrow Bledsoe proposed an algorithm that determines obvious facial features. However, these measurements for the human brain (eye color, nose size, etc.) do not really make sense for a computer considering individual pixels in an image. Researchers have shown that the most accurate approach is to let the computer measure what it needs. Deep learning, determines which parts of the face need to be measured, better than humans.

To solve this problem, a convolutional neural network of deep learning is being created, which generates 128 dimensions (a face map) for each person. The idea of converting images into a list of computer-generated numbers is extremely important for machine learning (especially for automated translation).

To train the network, 3 images are analyzed:

1. Educational image of a famous person's face
2. Another photo of the same famous person
3. The image of a completely different person

The algorithm then looks at the measurements it makes for each of these three images. Then he tweaks the neural network a bit [15].

Database "The ORL Database of Faces".

The first test task was the problem of face recognition. The database consists of 400 photo graphs of forty different people (Fig. 1). All photos are presented in grayscale. The formation of the test sample is as follows: it is necessary to randomly select one photo of each person. The algorithm being developed should classify the remaining 40 based on 360 training photographs, i.e. identify the people depicted on them [14].

The following were selected as test tasks: "The ORL Database of Faces" and "The Facial Expression Recognition 2013".

Experiment

CNN	Train data	Test data	Accuracy
ORL Database	360	90	91%
My Database of Student	420	80	89%

4.2 Random Forest

The pandemic situation taking place in the world has forced all people to wear medical masks for a long time, which is even an everyday accessory. This has become a real challenge for face recognition services and prompted the modernization of video surveillance systems, as masks block most of the surface of a person's face, preventing its correct identification. To solve this problem, the research area was focused around the eyes and nose to increase the reliability of the recognition system.

In the course of our research work, statements were taken into account, which led to the conclusion that the recognition system works correctly in medical masks. Most have formed the opinion that the mask covers only 40-50% of a person's face, and the remaining 50% is enough for successful identification. The dimensions of the human face are different, the width of the head varies between 54-65 cm, the mask also has different sizes and types, and therefore one person may have 20% of the face open, and another – 70%. This difference affects the quality of recognition. There is a claim that the facial recognition system includes images of high enough quality to capture individual features in the uncovered part of the face. CCTV cameras form images of people in various lighting conditions, which significantly affects the quality of facial recognition. In addition, it should be borne in mind that if a person, in addition to a mask, wears accessories such as a headdress, glasses, a handkerchief, then a very small part of the face area remains for identification. It is known that if such situations happen, then the most necessary informative feature for face recognition is the human eye. This paper examines the issues of correct face recognition through the eyes in conditions when a person's face is not fully visible.

The random forest method is based on the method of decision trees. A random forest is a set of decisive trees, and the class of the object that has passed the classification is chosen by a majority of votes. Generate a random sample S of size l based on the original training sample [17]. D = xi, yii l . By sampling S, induce a non-truncated decision tree Ti with a minimum number of observations at terminal vertices equal to nmin, recursively following the following subalgorithm:

1) from the initial set of n features, randomly select p features,

2) from p features, select the feature that provides the best splitting,

3) split the sample corresponding to the vertex being processed into two subsamples.

As a result, we get an ensemble of decision trees.

A machine learning algorithm consisting in the use of a committee of decision trees. The main idea is to use a large ensemble of decision trees, each of which in itself gives a very low quality of classification, but due to their large number, the result is good. Since the accuracy of SVM is higher than that of Random Forest, it is necessary to use it as a classifier [7].

As a result of the work done, a computer vision system was designed to recognize basic faces from the image. This system detects all the basic faces with an accuracy of 97.92%, while it consumes a very small amount of computer resources, compared with analogues.

Experiment

Random Forest	Train data	Test data	Accuracy
library DLIB	5400	1350	71%
My Database of Student	420	80	63.5%

4.3 Hidden Markov models (CMM, HMM)

Currently, there is an increased interest in various methods of identification of persons. To solve this problem, it is necessary to perform two steps: to detect the face in the photo and recognize it. We will focus on the problem of recognition using hidden Markov models (HMM).

Hidden Markov models are one of the statistical methods of face recognition. When working, this method uses statistical signals and spatial characteristics. The elements of this model are: a set of observed states, a set of hidden states, a matrix of transient probabilities and an initial house element of this method corresponds to its own Markov model. In the process of image recognition, all Markov models generated for the search objects are searched and the maximum probability is searched, taking into account that the sequence of observations for this object is generated by the corresponding model. At the time of writing, this method is not used in the commercial sphere. The accuracy of image recognition for this method, according to the test results, is about 95%.

The HMM elements are a set of observed symbols (observations in this case are the coefficients of the discrete cosine transformation of a photograph of a person's face with a scanning window of some size), a set of different states, a set of observed symbols, a vector of initial states, a matrix of transient probabilities, a matrix of probabilities of observed symbols.

The possibility of applying HMM to the task of face recognition is due to the fact that[11]:

1. In the existing sequence of pseudorandom variables (face fragments), we can assume that each observation is independent of the previous ones;
2. Each random variable gives a measurement whose probability distribution depends on the state.

Building An Embedded Hidden Markov Model

- Uniform partitioning of input vectors by states;
- Initializing the model;

- Application of Viterbi partitioning for embedded SIM. At this stage, the input vectors are redistributed by states.
- We evaluate the resulting model, and either go back to the previous step, or say that the desired model is built

Recognition process in a Hidden Markov Model

- The system is fed some image to the input;
- The system builds an input sequence from it;
- The system plots the probabilities of constructing such an input sequence by all models;
- The most likely answer and the probability of matching are given.[9]

The recognition task is divided into two subtasks: at the HMM training stage, it is necessary to build a model based on a set of different images of a particular person's face stored in a database; at the recognition stage, some proposed image should be attributed to one of the models with some probability.

Advantage of the method:
High accuracy of image recognition.
Disadvantage of the method:
During the execution of the algorithm, it is necessary to perform a lot of calculations, therefore, the work time increases. Forward and reverse algorithms have been developed to optimize the problem. It is necessary to select model parameters for each set of elements. Which will be searched for. Also, this algorithm does not have a discriminating ability - this learning algorithm only maximizes the response of each image to its model, but there is no minimization of the response to other models.

Experiment

HMM	Train data	Test data	Accuracy
ORL Database	360	90	70.3%
My Database of Student	420	80	60.1%

4.4 Principal component analysis

The principal component analysis, or principal component analysis, PCA, is one of the well-known methods of object processing, which is based on the Karunena-Loeva method. Initially, this method was used in statistics to reduce the feature space without significant loss of information. In facial recognition technology, it is used to represent a face in the form of a vector of small dimension (principal components), which is compared with a set of vectors of a group of images that are searched for. The main goal of this method is to minimize the feature space in such a way that it maximally describes the current images describing a set of faces. Thanks to the use of this method, it is possible to identify various changes in the training sample and describe it using several orthogonal vectors, called their own. This list of vectors can be used to encode other images of faces that are a weighted combination of these eigenvectors. By applying a certain number of vectors, it is possible to obtain a compressed approximation to the input image of a face, which can subsequently be stored in a set of search data, for example, in a database, in the form of a vector of coefficients, which is also the key for searching for faces in the data array. The algorithm of the principal component method consists of a number of operations. First, the training set is transformed into a data matrix, where each row is a single instance of the face mapping, represented in a string version. All elements of the matrix should be reduced to the same length (the longest element), and also have normalized histograms. The next step is to normalize the matrix, calculate the zero mean and the first variance, as well as the covariance matrix. At the final stage of the algorithm, the eigenvectors are sorted in descending order by the first k vectors according to the rule Xf=1, where x are column vectors, is the root of the variance of the vector along the main component i, the coordinate that is divided for normalization.

To solve the problem of identification of persons, the Principal Component Analysis (PCA) method was used — one of the main methods of reducing the dimensionality of data with the loss of the least amount of information [5]. It is also used in econometrics, bioinformatics, image processing, as well as for data compression, etc. The faces in the principal component method are represented as a linear combination of weighted eigenvectors called Eigenfaces. These eigenvectors are derived from the covariance matrix of the image database. The number

of own faces received (100) will be equal to the number of images in the database. In the presented work, images in shades of gray were used, the pixel brightness values of these images are in the range from 0 (black) to 255 (white).

This method is actively used in practice, but in case of a change in illumination or facial expression, its effectiveness decreases. This is explained by the fact that this method chooses a space with such a purpose as to maximally approximate the set of input data, and not to discriminate between classes of persons. To solve this problem of their values and leave, a method using a linear Fisher discriminant was proposed, in the literature it has the names Fisherface, LDA.

Differences between LDA and PCA methods

Both of these methods perform dimensionality reduction of input data while maintaining quality. However, they have a difference.

The PCA method looks for a projection of data in which the classes are linearly separable.

The PCA method looks for a projection of data in which the spread across the entire database of persons without taking into account classes will be maximized.

Because of this difference, the search accuracy of the LDA method is higher than that of the PCA method and is 95% versus 56%.

Advantage of the method:

Thanks to the vector representation of images in the data array, it is possible to store a large number of images and perform a fairly fast search. If there are components to search for, such as race, gender, lighting, images will be found by the specified components.

Disadvantage of the method:

High requirements are applied to the output images: high illumination, the same angle, before applying algorithms, it is necessary to carry out high-quality image processing: remove noise, adjust brightness and contrast, etc.

Experiment

PCA	Train data	Test data	Accuracy
ORL Database	360	90	79.3%
My Database of Student	420	80	85.1%

4.5 Active Appearance Models, AAM

Active appearance models are statistical image models that are adjusted to the image by means of various deformations. This method was proposed by T. Cootes and K. Taylor in 1998. Initially, this method was used as an assessment of the parameters of facial images. This model contains two types of parameters: parameters related to the pixel structure of the image (appearance parameters) and parameters related to the shape (shape parameters). Before use, you need to train the model on pre-hand-marked images. Each model label has its own number and defines the base point that the trained model should find when analyzing a new image. The algorithm of the classical method of active appearance models consists of the following steps. First, all the shape parameters and affine transformations are calculated - reflections of the plane into itself. The second step calculates the error vector S t . With the help of piecewise deformation of the image, the texture of the analyzed image is extracted. The next step is to calculate the perturbation vector S p = R S t . At the fourth iteration step, affine transformations and the vector of combined parameters are updated by adding the obtained values of the perturbation vector to the current values. In the next step, the texture and shape are updated. Finally, at the last step of the iteration, convergence is checked, otherwise the transition to the second iteration is carried out. The given algorithm for solving the classical method has a disadvantage - slow convergence and large calculations in the process, as a result of which it is limited in application. This problem is solved by a mathematically efficient algorithm of the active model of the appearance of the composition proposed by Matthews and Baker, based on the Lucas-Canada approach. This algorithm uses Newton's method to find the minimum in the error function. This algorithm searches for the minimum root-mean-square error between the real image and the template. During the calculations, the template is deformed taking into account the vector of parameters that maps the pixels of the template to the pixels of the real image. Since this algorithm is a classical appearance model using optimization, it inherits all the properties of the classical model. Therefore, before using this model, it is necessary to train. The process of learning an active model of the appearance of the reverse composition involves calculating a group of images of the steepest descent. One of the software products implementing this method is

the AAMToolbox library. This library is distributed under license and is intended for non-commercial use only. The recognition accuracy of this method, according to the results of numerous tests, was 95% [11].

AAM are built during the preparatory stage. In active appearance models, two types of parameters are modeled: shape-related parameters (shape parameters) and parameters related to a statistical image model or texture (appearance parameters). Before use, the model is trained on pre-marked images. Marking is carried out either manually or in semi-automatic mode. Each label has a number and defines a characteristic point that the model will have to find when adapting to a new image.

Advantage of the method:

High accuracy of image recognition.

Disadvantage of the method:

This method uses images partially; for the algorithm to work, it is required to mark up the image; in the process of comparison, each image is considered as independent, an individual calculation is made for it, which slows down the algorithm's operation time.

Experiment

AAM	Train data	Test data	Accuracy
ORL Database	360	90	55.7%
My Database of Student	420	80	66.2%

5. Conclusion

In this thesis, the ring system was described simply, how much it is needed or whether it is relevant at the moment. Thus, I considered different platforms, just ring systems such as Hackerank, Examus. We steamed the photos from the hack gear and collected all the data into one file (folder). To check for plagiarism and facial recognition, we considered methods related to Machine learning and computer vision. Also, a description of the use of computer vision in the modern world and the five main methods of facial recognition was given, as well as a comparison of these methods according to various criteria. The key parameter for comparison was the accuracy of image recognition and the operating time of the method. According to the analysis, the best method for practical application is the principal component method using the Fisher linear discriminant. Its recognition accuracy was 95.5%.But this results shows best result only to my database, but according to "ORL database" better accuracy gives CNN model. And that's why I strongly able to say that this two model are better than other one. Despite the fact that there is a more accurate algorithm for flexible comparison on graphs, it is limited in application due to the long running time - to use it, calculations must be performed on a cloud server or use a computer with appropriate system resources. Also, the method of the main components has a flexible setting that allows you to search by gender, race, lighting and other criteria, so that this method stands out from others.

6. Future Work

We have now finished the most important part of the study. As I said in the main part of my work, I use a Python script to recognize the faces of the students I have collected and check them to see if they belong to the person taking the exam or to someone else. At the moment, most or the main part is done, and in the future I will use other CV and ML algorithms to solve problems like:

- Detection of strangers;
- The presence of other electronic devices in the image, like phones or headphones;
- Mouth open or close detection;
- Eye gaze tracking;
- Video recordings;

I will also try to publish the results of my work and share them with other researchers in this field of the sphere. If necessary, make the product available to everyone and show it to other institutions.

References

[1] Timo Ahonen, Abdenour Hadid, and Matti Pietikainen. "Face description with local binary patterns: Application to face recognition". In: *IEEE transactions on pattern analysis and machine intelligence* 28.12 (2006), pp. 2037–2041.

[2] Eren Bilen and Alexander Matros. "Online cheating amid COVID-19". In: *Journal of Economic Behavior & Organization* 182 (2021), pp. 196–211.

[3] Phil Maguire, Rebecca Maguire, and Robert Kelly. "Using automatic machine assessment to teach computer programming". In: *Computer Science Education* 27.3-4 (2017), pp. 197–214.

[4] Sarthak Maniar et al. "Automated Proctoring System using Computer Vision Techniques". In: *2021 International Conference on System, Computation, Automation and Networking (ICSCAN)*. IEEE. 2021, pp. 1–6.

[5] Khalil Mohsen. "POST-PANDEMIC FOREIGN LANGUAGE COMPETENCY TESTING THROUGH MODERN PLATFORMS AT RUDN UNIVERSITY". In: *Вестник современной науки. Серия: Гуманитарные науки* 1 (2021), pp. 81–91.

[6] Ualikhan Sadyk et al. "Effective Ways to Pass Exams in Programming Disciplines and Optimize the Process of Analyzing Results. Case Study: Suleyman Demirel University". In: *2021 16th International Conference on Electronics Computer and Computation (ICECCO)*. IEEE. 2021, pp. 1–3.

[7] ЕН Амиргалиев et al. "ОБ ОДНОМ ПОДХОДЕ РАСПОЗНАВАНИЯ НЕЧЕТКИХ ИЗОБРАЖЕНИЙ ЛИЦ НА ОСНОВЕ АНСАМБЛЯ". In: *Вестник Восточно-Казахстанского государственного технического уни им. Д. Серикбаева* 2 (2021), pp. 59–70.

[8] Елена Владимировна Анашкина and Елена Федоровна Валяева. "Проблем нарушения академических норм при компьютерном контроле знаний в высших учебных заведениях". In: *Education sciences and psychology* 6 (2014), pp. 27–37.

[9] Петр Базанов and Оксана Джосан. "Методы выделения информативных признаков изображений лица в задаче распознавания лица". In: *Computer Graphics and Applications (GraphiCon'2005), Fifteenth International Conference*. 2005.

[10] Википедия. *Задача классификации — Википедия, свободная энциклопеди* [Онлайн; загружено 30 мая 2022]. 2022. URL: `https://ru.wikipedia.org/?curid=524472&oldid=122913809`.

[11] Татьяна Александровна Гультяева. "Применение скрытых Марковских моделей с одномерной топологией к задаче распознавания лиц". In: *Россий научно-техническая конференция" Информатика и проблема телекомм Материалы российской научно-технической конференции. Новосибирск: СибГУТИ*. 2006, p. 150.

[12] ДС Добровинский, ИВ Ловецкий, and МА Попов. "Прокторинг как инструмент развития дистанционного образования". In: *Научно-техничес и экономическое сотрудничество стран АТР в XXI веке* 2 (2018), p. 27.

[13] Оксана Евгеньевна Логачева and Вячеслав Владимирович Костюченко. "Алгоритмы распознавания лиц". In: *Моделирование, оптимизация и информационные технологии* 4 (2016), pp. 17–17.

[14] ДВ Плотников and ЕА Сопов. "Решение задач распознавания лиц и мимики с помощью сверточных нейронных сетей". In: *Решетневские чтения* 21-2 (2017), pp. 234–236.

[15] Наталья Александровна Попова, Михаил Александрович Назаров, and Максим Вячеславович Власов. "Решение задачи распознавания лиц с использованием алгоритмов машинного обучения". In: *Моделирование, оптимизация и информационные технологии* 6.1 (2018), pp. 408–415.

[16] АС Потапов. "Системы компьютерного зрения. Учебное пособие". In: *СПб: Университет ИТМО* (2016), pp. 10–18.

[17] АВ Рытов. “РАЗРАБОТКА КОМПЬЮТЕРНОГО ЗРЕНИЯ ДЛЯ РАСПО БАЗОВЫХ ЭМОЦИЙ ПО ИЗОБРАЖЕНИЮ”. In: *ПРИКЛАДНАЯ МАТ И ИНФОРМАТИКА: СОВРЕМЕННЫЕ ИССЛЕДОВАНИЯ В ОБЛАСТ ЕСТЕСТВЕННЫХ И ТЕХНИЧЕСКИХ НАУК*. 2020, pp. 95–99.

[18] К Свириденко. “Прокторинг–надежный способ получить объективную оценку навыков кандидатов”. In: *URL: https://finassessment. net/blog/prok nadezhnyj-sposob-poluchit-obektivnuyu-otsenku-navykov-kandidatov (дата об 13.03. 2020 г.)* (2017).

[19] А Скшидлевский. “Опыт разработки автоматизированной системы прокто для подтверждения результатов онлайн-экзаменов”. In: *Хабрахабр.–2017.– Режим доступа: https://habrahabr. ru/post/325296/.–Загл. с экрана* (2017

[20] Л Шапиро and Дж Стокман. “Компьютерное зрение= Computer Vision”. In: *М.: Бином. Лаборатория знаний* 752 (2006), p. 11.