Eye Blink Detection and Alarm System to Reduce Symptoms of Computer Vision Syndrome

Atheer K. Alsaif and Abdul Rauf Baig

College of Computer and Information Sciences, Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh 11432, Saudi Arabia

Abstract
In recent years, and with the increased adoption of digital transformation and spending long hours in front of these devices, clinicians have observed that the prolonged use of visual display units (VDUs) can result in a certain symptom complex, which has been defined as computer vision syndrome (CVS). This syndrome has been affected by many causes, such as light refractive errors, poor computer design, workplace ergonomics, and a highly demanding visual task. This research focuses on eliminating one of CVSs, which is the eye dry syndrome caused by infrequent eye blink rate while using a smart device for a long time. This research attempt to find a limitation on the current tools. In addition, exploring the other use cases to utilize the solution based on each vertical and needs.
Keywords:
Computer vision, Eye blinking, Covered face, Niqab, Yolo, CV, Computer vision syndrom

1. Introduction

In recent years, and with the increased adoption of digital transformation, clinicians have observed that the prolonged use of visual display units (VDUs) can result in a certain symptom complex, which has been defined as computer vision syndrome (CVS). Computer vision syndrome (CVS) or digital eye strain is "a complex of eye and vision problems related to near work experienced during computer use.". Abudawood, G. A., Ashi, H. M., & Almarzouki, N. K. (2020) said (CVS) is one of the rising health concerns related to technology (cell phones and tablets) due to Spending long hours in front of these devices. This syndrome has been affected by many causes, such as light refractive errors, poor computer design, and workplace ergonomics, and a highly demanding visual task, which can all contribute to the development of visual symptoms and complaints.

As Gowrisankaran, S., & Sheedy, J. E. (2015) said Computer vision syndrome comes with different symptoms of CVS can be broadly classified into four main types: visual, ocular surface-related, asthenopic and extraocular, as depicted in Table 1. In addition, Gowrisankaran, S., & Sheedy, J. E. (2015) said the symptom severity is related to the exposure time to the devices, the nature of the visual task, the workplace environment, and the person's visual abilities.

Prevention or reduction of Computer Vision Syndrome (CVS) symptoms can be made in many ways. Jumpamule, W., & Thapkun, T. (2018, November) suggest following the 20-20-20 rule (take a 20-second break to view something 20 feet away every 20 minutes). On the other hand, and Gowrisankaran, S., & Sheedy, J. E. (2015) mentioned that frequent blinking could reduce the syndrome. Nowadays, an intelligent tool is required to encourage the user to follow this rule and aware of computer safe using either from time, position, or any other aspect. In this research, we propose Eye blink detection and alarm system that reduce Ocular surface-related symptoms of Computer Vision Syndrome.

During our new normal life, the smart device is a mandatory tool to do our jobs, read the news, doing government procedures, and much more. With this increase of using smart devices, there is a huge increase in Computer Vision Syndrome (CSV) equally. This can be challenging for the worker, pupils who work for long hours in front of screens. In Saudi Arabia and based on We Are Social agency, +24 million people grouped in population (16-64); this group of population owns: 98.7% smart phone, 64% laptop and PC, 29.2% smartwatch, and 22.9% game counsel. Besides, the users spend 7H 45M using internet through all type of devices, where this will increase the possibility of CVS. Reporting to American Optometric Association, greatest risk for developing CVS are those persons who spend two or more continuous hours at a computer or using a digital screen device every day.

In another research done on 275 medical students at KSU aimed to assess the effects of CVS among health care professionals who study via electronic methods versus hard copy methods or both. As conclusion from the study result that a student whose studying from electronic methods led to an increased incidence of CVS, and females using electronic methods have a higher chance of developing CVS. In their study, reported that the Intensity of symptoms vary between 22.6% to 4.0%; where headache was the maximum number followed by, pain, tearing, dryness, etc. And due the mandatory of use smart devices these days, some important factors in preventing or reducing the

Manuscript received May 5, 2023
Manuscript revised May 20, 2023
https://doi.org/10.22937/IJCSNS.2023.23.5.21

symptoms of CVS shall be activated such as lighting conditions, chair comfort, location of reference materials, the position of the monitor, blinking, and the use of rest breaks. This study seeks to address the limitation on eye blinking techniques for Computer Vision Syndrome prevention (eye blinking detection AI model).

Always wonder about the impact of our today lifestyle on many aspects of our life in the future, especially health. will the evolution of use of smart devices negatively impact our health? either mental health or physical health and how we could prevent any. As known, Prevention is better than cure, and health is the most valuable asset of a person. For that, this study attempts to utilize the new technology to save people's health and especially for eye health & reduce Computer Vision Syndrome (CSV). The findings of this study rebound to the benefit to the whole society eye health beginning by children, students, workers, and any person in this world who use the smart devices on a daily basis.

The aim of this research is to find the limitation on monitor eye blinking current methods using available classification techniques. The main objectives of this research are:

- To explore the current solutions and determine the optimal one to prevent eye ocular surface-related syndrome.
- To explore the use cases of eye blinking.
- To assess the current challenges and future improvement opportunities (ex: cybersecurity concerns, limitation, etc.).

This research has been organized into 2 main chapter as follows:

1. Introduction:

   This chapter outlines the main research questions and objectives of this study that help to accomplish an approach for automation the eye blinking monitoring. Moreover, the scope of the study and structure of this thesis are also provided in this chapter.

2. Literature review:

   This chapter shows different latest techniques for eye blinking classification model. It compares and evaluate these techniques in order to identify the research gaps and then to develop a tool for monitoring eye blinking tool and reminder.

2. Literature Review

In the past years, significant progress has been exploring new innovative techniques and methods for preventing Computer Vision Syndrome, each techniques is suitable according to given conditions.. Before a few years, Jumpamule, W., & Thapkun, T. (2018) proposed a new reminder system that constantly monitors the use of a smartphone in real-time for periodic breaks (and produces a warning and some practical advice) to slow down at least one level of CVS symptoms [2]. On the other hand, Lemma, M. G. (2020) was focused on assessing CVS and associated factors among secretaries working in government ministry offices. Besides, Anggrainy, P., Lubis, R. R., & Ashar, T. (2020) study and analyze the effect of trick intervention 20-20-20 on the incidence of computer vision syndrome in computer workers [4]. Many researchers' have put many efforts into this subject from a different perspective to prevent CSV. While Sheppard, A. L., & Wolffsohn, J. S. (2018), mentioned that symptoms might be split into those linked to dry eye (external symptoms) and internal symptoms related to ametropia, accommodation, or vergence problems [6], and this open doors for us to investigate more in a different area in ophthalmology sciences.

As the reduced blink rate is a risk factor for a dry eye disorder, therefore, Ashwini, D. L., Ramesh, S. V., Nosch, D., & Wilmot, N. (2021) proposed a blink-blink software innovative solution to remind to blink while using computers. This system has been tested for 15 days with 8 reminders/min and results in improved DED-related symptoms by increasing the blink rate. The carry-over effect after cessation of Blink Blink software in improving blink rate was maintained even after 1 month. Trial Registration: Clinical Trials Registry India (CTRI): CTRI/2018/08/015176

All the mentioned examples are based on the eye blinks reminder system, while there are many different techniques for blinking detection, where that will enhance the remining process. There are many existing approaches to detect eye blink, EOG electrodes, proximity sensor frame, or camera-based system. All the approaches have advantages and disadvantages that are complex in nature. In our research will cover this subject from the most efficient way of eye blinking; through image/video processing by webcam specially for covered face with Niqab.

2.1 Application of Eye tracking/blinking detection & reminding system

With the fast move in the using digital solution and specially the artificial intelligence, many use case has been appeared to serve humanity & business demand. During the pandemic many AI use cases showed up to raise the healthcare industry service level, also in financial service a large transformation has been happened. For the facial recognition and eye blink in specific there are different use cases in different industry, for instance: the safety and security, Healthcare, e-commerce &gaming, Education, etc. In the below sub sections listed all the use cases in detail.

2.1.1 Safety & security use cases

(i) Lie/Deception Detector System:

According to the science of psychology (Soorjoo, Martin. 2009) Eye blinking is one of the indicators for knowing people lie or not by increasing the number of blinking, in addition, the eyes will be dilated.

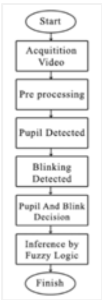


Figure 1 Lie

Paper 1: ***Lie Detector with Pupil Dilation and Eye Blinks Using Hough Transform and Frame Difference Method with Fuzzy Logic***

(Nugroho, R. H., Nasrun, M., & Setianingsih, C. (2017, September), it utilized the analytics capabilities to conduct a lie detector, starting by measuring the change in pupil dilated using circular hough transform method and increase the number of blink of the eye by frame difference method. And as a result from this study, lies people pupil dilatation of 4% to 8% of the initial pupil diameter and an increase in the number of blinking of the eye up to 8 times from the initial blink of the respondent before the question is asked. On this research the accuracy of lie detector system is 84%.

Paper 2: ***Eye blink count and eye blink duration analysis for deception detection***

George, S., Pai, M. M., Pai, R. M., & Praharaj, S. K. (2017, September). This a psychological experiment was conducted for deception detection, wherein the blink count and blink duration of the 50 subjects were analyzed for truth and lie responses for 10 control questions.

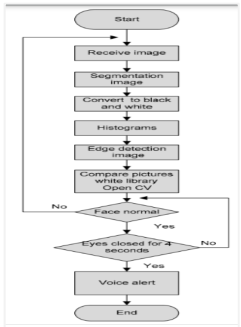


Figure 2 Detection Eye Blink methodology

The questions are related to name, age, place, house, marital status, entertainment, food and religion. In this experiment, a facial articulation analysis techniques and eye distance calculation formula for eye blink analysis has been used, and short distance means eyes are closed. This formula build by using left eye lower (eyeLL), left eye upper (eyeLU), right eye upper (eyeRU) and right eye lower (eyeRL). The result shows that blink duration and blink count are more while lying.

Figure 3 Eye blink count and eye blink duration analysis for deception detection

(ii) Authentication and Authorization

Paper 1: ***Eye gesture blink password: a new authentication system with high memorable and maximum password length***In Salehifar, H., Bayat, P., & Majd, M. A. (2019) paper, build a Eye Gesture Blink Password authentication system EGBP, based on eye movement analysis.

Figure 4 Eye gesture blink password

(iii) Work safety

Paper 1: The Detection Eye Blink on Working Production Line in Industrial

The Phatchuay, S., Yooyen, A., & Ketcham, M. (2016, June). paper proposed the program of surveillance human behavior on working industrial environment by image processing for eye blinking. If the employee over 4 seconds, the system will alert by sounds. It showed that the program accuracy can detection behaviors the blinks of eye four meters in phase is 96% of accuracy. However, there are some limitations with the work environment, causing some errors such as the light level, either too bright or too dark and the resolution of the images obtained changes accordingly. Therefore, the accuracy of the system has been reduced.

Figure 5 Detection Eye Blink on Working Production Line

The eye movement analysis and blinking detection has un limited number of use cases, in different industries.

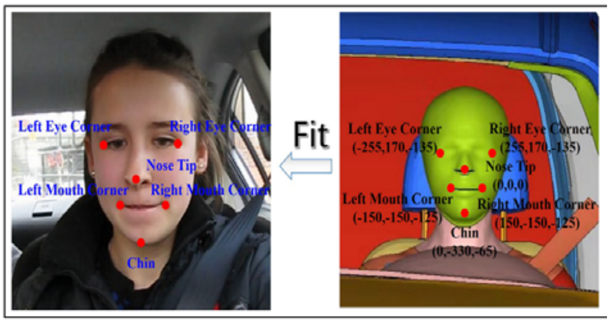


Figure 6 Li, X., Xia, J., Cao, L., Zhang, G., & Feng, X. (2021). Driver fatigue detection

Figure 8 Wang, Y., Wang, L., Lin, S., Cong, W., Xue, J., & Ochieng, W. (2021) Effect of Working Experience on Air Traffic Controller Eye Movement

As the reduced blink rate is a risk factor for a dry eye disorder, therefore, Ashwini, D. L., Ramesh, S. V., Nosch,

2.1.2 Healthcare use cases

Human computer interaction (HCI) Assisting System for disabilities.

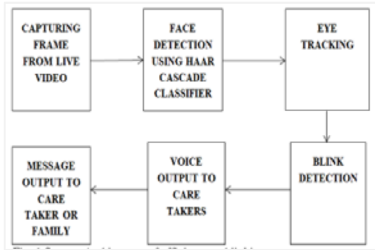


Figure 9 Eye Blink to Voice for

Paper 1: iChat: Interactive Eyes for Specially Challenged People Using OpenCV Python

The main challenge in communication for disabilities is the inability to use the hand for chatting, and communication. Kathpal, K., Negi, S., & Sharma, S. (2021, September). Proposed an app to help millions of paralysis through utilizing eye movement, and eye blinking in typing and chatting environment without the use of hands. The methodology is based on analyzing the 68 facial points

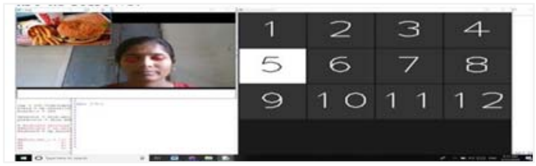


Figure 7 Eye Blink to Voice for Paralyzed Patients

dataset which must be present in every face specifically the eye, nose, jaw, etc. The project built over Kivy platform, an open-source platform, includes detection of eye blinking, tracking the eye movement right or left from the webcam/mobile camera using OpenCV library in python.

Paper 2: Eye Blink to Voice for Paralyzed Patients

Jebakani, S., Divya, J., Megha, S., & Santhosh, H. (2020). Proposed a framework helping Paralyzed Patients to speak with their own eye squint and get their prerequisites satisfied via overseers. The proposed framework gives an effective and exact outcome when contrasted with the current manual situation.

In a brief, the implemented system is built by two main modules they are face detection and eye detection, the coded algorithm first detects the face using a facial landmark detector that is implemented inside dlib library and then detects the eye region and draws a square box around the detected eye coordinates using OpenCV. The crosser coordinate will move to each number As shown below each number, where each number gives a voice message about food, water, or help as well as displays the image of the required thing. Every number has a corresponding requirement assigned to fulfill patient needs respectively, in addition the requirement sent to the family members and caretaker.

2.1.3 E-Commerce & eGaming use cases.

E-commerce and user experience

Paper 1: A Multimodal Measurement Method of Users' Emotional Experiences Shopping Online

Emotions play an important role in the design of e-commerce websites. A website should satisfy its users' emotional needs. Guo, F., Cao, Y., Ding, Y., Liu, W., & Zhang, X. (2015) proposed a multimodal measurement method conjoint using questionnaires, eye tracking, and physiological measures to understanding users' emotional needs while the users are interacting with e-commerce websites. Fig 11 compares participants' eye movement characteristics when shopping from 2 different websites. There were significant differences in values for average pupil size, fixation count, blink count, blink frequency, saccade frequency, and saccade count. In addition, Kamangar, A. (2020). Did a massive work in the use of an eye tracker on e-commerce websites in either the consumer neuroscience or marketing research literature. And the findings of literature review, show that the correlation and affect between customers such as age, gender, nationality, etc. and the website design.

	Website 1		Website 2	
Indexes of Eye Movement	*M*	*SD*	*M*	*SD*
Average pupil size (px)	13.21	1.87	14.34	2.01
Fixation frequency (count/s)	2.12	0.50	1.99	0.36
Fixation count (count)	664.15	347.30	434.33	200.98
Average fixation duration (ms)	227.09	48.46	214.23	57.90
Blink count (count)	36.74	19.69	18.52	10.04
Blink frequency (count/s)	0.14	0.05	0.11	0.04
Average blink duration (ms)	3435.44	2070.69	3595.20	1484.91
Saccade frequency (count/s)	1.89	0.52	1.63	0.51
Saccade count (count)	514.45	258.85	332.48	168.22
Average saccade duration (ms)	52.44	17.54	55.84	25.01
Average saccade amplitude (°)	5.70	2.22	5.71	2.47
Average saccade velocity (°/s)	82.73	9.87	79.67	11.88

Figure 10 Comparison of Eye-Movements When Shopping on Websites 1 and 2

Online gaming

Paper 1: Immersive experience influences eye blink rate during virtual reality gaming

The gaming technology and tools have improved within the last years, and VR one of the tool that changed the way of playing in 3D mode. Ishiguro, T., Suzuki, C., Nakakoji, H., Funagira, Y., & Takao, M. (2019), tested the correlation between blink rate with VR gamed based. results indicate that the eye blink rate is increased by the sense of spatial presence and can be a good measure of subjective immersive experience in a VR environment.

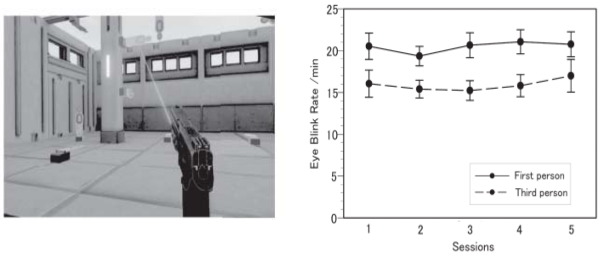


Figure 11 The variation of gunshots and eye blinks in consecutive sessions

2.1.4 Education use cases

Paper 1: A Novel Deep Learning-based Online Proctoring System using Face Recognition, Eye Blinking, and Object Detection Techniques

During the pandemic, the online learning was the only option to ensure the education continuous, and many emerging technologies has been utilized to support this vision. For example, student monitoring during classes and mainly during exams was not easy to monitor millions of students simultaneously from various locations. Therefore, automated proctoring methods and technologies are provided to detect unfair, unethical, and illegal behavior during classes and exams through using the face recognition and object identification.

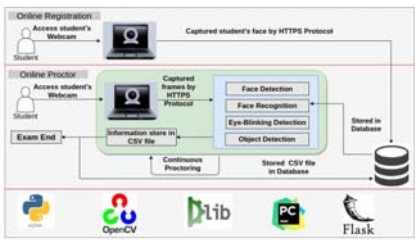


Figure 12 Online Proctoring System Architecture

2.2 Review on various Eye blink detection techniques

In the past few years, video analytics, and intelligent video analytics, have attracted increasing interest from both industry and the academic world for the enormous advances made in deep learning that automate tasks with minimum operational work. In this paper, some previous methods been explored either active or passive. Cech, J., & Soukupova describe the Active methods as a reliable but use special hardware, often expensive and intrusive, e.g., infrared cameras and illuminators, wearable devices, glasses with a special close-up camera observing the eyes. While the passive systems rely on a standard remote camera only and this highly depends on the use cases. Then In order to find the gap in all available options, we assigned some criteria that might affect the eye blink system usability for many situations besides its accuracy, perception, and recall and proposed the best approach. Prior going in details of technology, listed below the most application of eye blinking.

Artificial intelligence and modern technologies will continually grow in all areas, which confirms the importance of developing these capabilities to comply with future market requirements. In the upcoming section, we will focus on eye-blinking techniques and how we can enhance them to serve all types of people in different situations. In the below table, we summarized some of the currently available and tested techniques related to our eye blink techniques beside its limitations. In general, all the gathered data are procced by deferent model, where the improvement appears. The differences between the model and its pros and cons are mentioned in the experiment section in detail. Prior to the evaluation between ML model, many experts use different of techniques to define the eye status. Below a brief summary of available eye blinking detection tool.

Figure 13 Camera based Eye-blink detection.

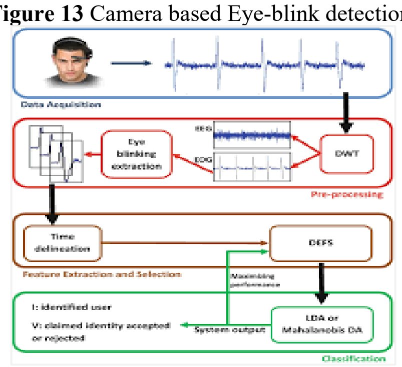


Figure 14 Eye Blinking using EOG Signals

Table 1 Eye blinking detection methods

Papers/ year	Objective	Method type	Eye blinking tool	Limitation and future work
DualBlink: A Wearable Device to Continuously Detect, Track, and Actuate Blinking For Alleviating Dry Eyes and Computer Vision Syndrome (2017)	Wearable device that can potentially alleviate computer vision syndrome and dry eyes.	Active	Infrared sensors through glasses.	• Long-term medical evaluation. • Infrared blink detection. • Integration into exiting augmented glasses and headsets for augmented and virtual reality.
Eye Blinking Detection for the Detection of Computer Vision Syndrome (2017)	system analyses this eye blinking rate and matches it with ideal eye blinking rate. When the eye blinking rate drops below the ideal value, alerts the user to pay attention at the eye blinking rate.	Passive	Image processing: face and eye detection followed by feature extraction using Speeded Up Robust Features(SURF) and Harris corner features.	• Decreasing the time consumed by our method and make it more fast.
Camera-Based Eye Blink Detection Algorithm for Assessing Driver Drowsiness	an adaptive camera-based eye blink detection algorithm for assessing the level of drowsiness during driving	Active	Camera-Based Eye Blink Detection Algorithm for Assessing Driver Drowsiness, the camera uses infrared illumination and provides a measurement of the eye closure for each eye	• Algorithm should be evaluated in real-world driving environments with various driving conditions including illumination and vibrations in the vehicle.
Eye Blink Detection Using Back Ground Subtraction and Gradient-Based Corner Detection for Preventing CVS	Proposed system could significantly reduce the symptoms among regular computer users leading to improved health habits.	Passive	Apply the Viola Jones algorithm and Kanade-Lucas-Tomasi (KLT) algorithm for detecting and tracking the eye in the video.	• Devising the optimal techniques in order to enhance the correctness in corner detection and background subtraction for more light weight video based applications.

2.2.1 The current available solutions (Eye blink detection ML model)

In order to come up with a better approach, we reviewed the most available methodology for an eye-blinking counter (Passive mode); below is the step for any eye-blinking counter solution. First, start by capturing the data, either from a live stream by the webcam or stored data. Then the heavy proccing started either by building any model or utilizing available libraries. Then closing with the system, count the blinks and remind the users to blink. The below section compares the available approaches and proposes the best approach for this project.

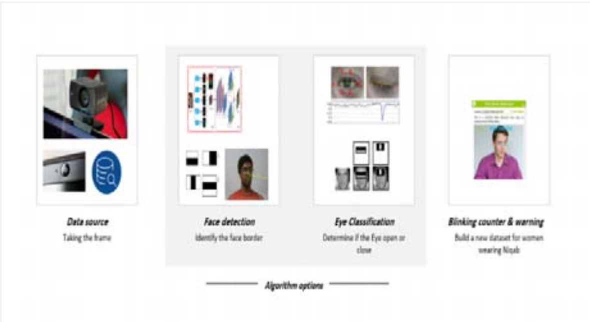


Figure 15 Current available solutions process

1. **Data source**

The first step of any system is data capturing, the eye blink information can be either live streamed by the webcam or previously recorded video from the database. We assume here all the compared model are based on passive mode (no additional component for data gathering like Arduino, external camera, head controller, etc.). and this has been discussed on the previous section 2.2.2 and the focus in this section, is the ML model to understand and process the data.

2. **Face detection & Eye classification (Algorithm options)**

Computer vision is a rapidly growing field devoted to analyzing, modifying, and creating a high-level understanding of images. The CV field enables computers and systems to derive significant information from digital images, videos, and other visual inputs — and take actions or make recommendations based on that information. In this stage, we will present many techniques available to help in Eye blinking detection and counting; below are some of them. Moreover, many excellent toolkits support developing machine learning software in Python, R, Matlab, and similar environments. Below is a brief of these tool kits and how to use them.

Manuscript received May 5, 2023
Manuscript revised May 20, 2023
https://doi.org/10.22937/IJCSNS.2023.23.5.21

1. **Toolkit:**

a) Dlib

As described by JMLR, Dlib is an open-source library which aims to provide a similarly rich environment for developing machine learning software. Towards this end, dlib contains an extensible linear algebra toolkit with built in BLAS support. It also houses implementations of algorithms for performing inference in Bayesian networks and kernel-based methods for classification, regression, clustering, anomaly detection, and feature ranking. To enable easy use of these tools, the entire library has been developed with contract programming, which provides complete and precise documentation as well as powerful debugging tools.

b) OpenCV:

Pulli, K., Baksheev, A., Kornyakov, K., & Eruhimov, V. (2012). Define Open CV as follow, OpenCV is aimed at providing the tools needed to solve computer-vision problems. It contains a mix of low-level image-processing functions and high-level algorithms such as face detection, pedestrian detection, feature matching, and tracking. The library has been downloaded more than three million times.

c) Pytorch:

PyTorch is an open-source machine learning (ML) framework based on the Python programming language and the Torch library. Torch is an open-source ML library used for creating deep neural networks and is written in the Lua scripting language. It's one of the preferred platforms for deep learning research.

d) Spyder

Spyder, the Scientific Python Development Environment, is a free integrated development environment (IDE) that is included with Anaconda. It includes editing, interactive testing, debugging, and introspection features.

e) Google Colab

Colab, or "Colaboratory", allows you to write and execute Python in your browser, with Zero configuration required, Access to GPUs free of charge, and Easy sharing.

f) Roboflow

Roboflow is a computer vision platform that allows users to build computer vision models faster and more accurately through the provision of better data collection, preprocessing, and model training techniques.

g) MediaPipe

Detector that computes and operates face locations on a full image and a 3D face landmark model that operates on the computed locations that predict approximate surface geometry using regression. MediaPipe Face Mesh is a solution that estimates 468 3D face landmarks in real-time.

h) Python

Computer programming language often used to build websites and software, automate tasks, and conduct data analysis.

2.2 Proposed machine learning model:

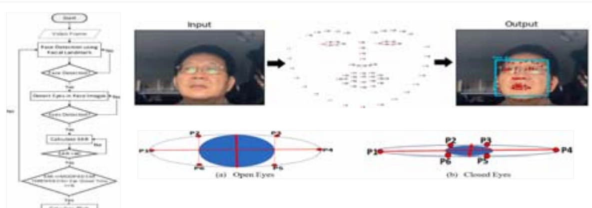
In this section, we will focus on eye blinking methods that work based on image/video analytics, therefore; 3 popular methods have been tested for eye blinking and all these methods done through python language. And to find the gap in all available options we assigned some criteria's that might affect the eye blink system usability for many situations besides its accuracy, perception, and recall. In the following section we will elaborate more on each method's features & its application, besides the full comparison based on authors test and previous work.

1. Proposed model: Face landmarks Algorithm

The facial landmark is detected using the 68-point system used in Dlib library. Face detection is accomplished using a facial landmark algorithm by Dlib, which leads to the identification of a face inside a frame. Once the face is detected we can extract the eyes coordinates based on the 68-point system, the eyes coordinates will help calculating the EAR (Eq.2), then compare it to the EAR threshold which set to 0.30. Morsi, Y. U. S. U. F., Maddireddy, P. R. A. N. A. V., & Diego, S. (2021) proposed a solution able to detect student drowsiness during the online classes and outputs a message to the student on a display as well as making noise with a buzzer to get their attention. As during Online Learning many problems have appear dozing Off is one of it and has gotten a lot worse. Many students, including ourselves, suffer to pay attention in online lectures and end up missing a major portion of the content. in order to solve this issue, Swaying attention has been created, a program that uses eye detection to track students dozing off and gives them a alert to stay focused. Many technologies has been used like Python, OpenCV, D-lib, Arduino-C code and a Sparkfun ESP32 board to build and test the prototype.

Key considerations:

- A new version of face landmark has been released to estimates 468 3D face landmarks, it's called MediaPipe face mesh.
- This model mechanism required identifying face border then face components, eyes, mouth, etc. below Eye blink detection flowchart based on Dewi, C., Chen, R. C., Jiang, X., & Yu, H. (2022).
- To distinguish between the open and closed states of the eye, they used an EAR Eye Aspect Ratio formula to calculate the threshold of 0.3. Dewi, C., Chen, R. C., Jiang, X., & Yu, H. (2022) describes the EAR equations, where P1 to P6 represent the 2D landmark positions on the retina. As illustrated in Fig. 3, P2, P3, P5, and P6 were used to measure eye height, while P1 and P4 were used to measure eye width. When the eyes are opened, the EAR of the eyes remains constant, but when the eyes are closed, the EAR value rapidly decreases to almost zero.



16 Face landmarks Algorithm process and EAR

2. Proposed model: Haar cascade Algorithm.

Haar cascade classifier method is proposed. According to Snehal B. Jagtap [8], the algorithm from Viola and Jones, called the Haar cascade classifier, is often used for face detection because it has advantages, such as detecting objects, including human faces, quickly. This method does not process the image by looking at the RGB value in every pixel but processes the image based on Haar-like features. Using Haar, start with face detection, then eyes; this does not work for veiled faces. Nguyen, N. D., Quang, N. D., Tin, D. T., & Dinh, A. (2020).

Key considerations:

- Haar cascade classifier (Face, eyes, etc) mechanism required identifying face border then face components, eyes, mouth, etc. below Eye blink detection flowchart based on Kamarudin, N., Jumadi, N. A., Mun, N. L., Keat, N. C., Ching, A. H. K., Mahmud, W. M., ... & Mahmud, F. (2019).

- To distinguish between the open and closed states of the eye, they used an EAR Eye Aspect Ratio formula equation.
- Haar Cascade is not giving accurate results whenever the subjects make any specific movements, based on Kamarudin, N., Jumadi, N. A., Mun, N. L., Keat, N. C., Ching, A. H. K., Mahmud, W. M., ... & Mahmud, F. (2019).

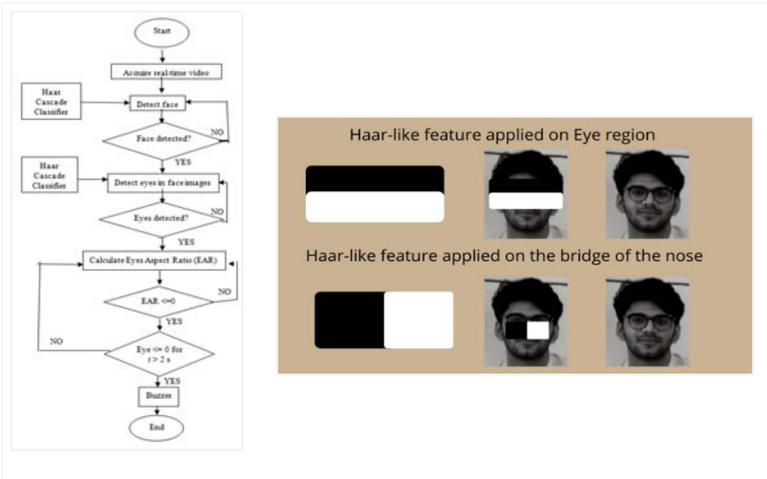


Figure 17 Haar cascade Algorithm process

3. Proposed model: CNN

Most eye status detection proposed methods are based on mathematical equations; contrary, the CNN method is not based on an explicit eye appearance model. Instead, the detection is based on a deep learning methodology. Anas, E. R., Henriquez, P., & Matuszewski, B. J. (2017) defined the way of CNN as a discriminant function that is learned from a large set of exemplar images of eyes at different states, appearances, and 3D positions. The convolution process starts by moving a convolution (filter) kernel of a specific size to the next image from the outcomes of multiplying the image with the filter used.

The results indicate that the system has successfully detected faces based on the specified algorithm. Asmara, R. A., Ridwan, M., & Budiprasetyo, G. (2021, September) experiment shows that CNN gives better detection accuracy than Haar Cascade. In addition, CNN is hardly used in mobile, wearable, and Raspberry Pi devices because of its GPU requirements. This means that the designed application can work and be used for the next steps in developing the Cloud-based face recognition application.

Key considerations:

- CNN required high GPU processing.
- CNN accuracy highly depends on the dataset quality, either prebuilt dataset or made for this specific project.
- CNN has different models and architecture selected according to the problem statement.

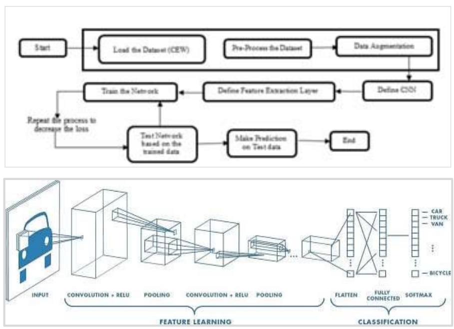


Figure 18 CNN process

The below table shows the gap between all available techniques, and based on the previous work and research experiment, the gap is to support eye blinking covered faces with Niqab

Method	Criteria						
	Source	Support covered face	Processing speed (H,M,L)	Eyeglass	face 360- or 180-degree level.	Realtime Analytics	Accuracy
Face landmarks by Dlib	*Paper* Haar Cascade Vs Facial Landmarks Technique for Face Recognition Uniqueness	No	NA	NA	No	Yes	%85
	GitHub code (researcher experiment)	No	H	No	Partially	Yes	NA
Haar cascaded classifier	*Paper* Haar Cascade Vs Facial Landmarks Technique for Face Recognition Uniqueness	No	NA	NA	No	Yes	%60
	GitHub code (researcher experiment)	No	M	No	No	Yes	NA
Convolutional Neural Networks	*Paper* Eye blink detection using CNN to detect drowsiness level in drivers for road safety	No	NA	No	No	Yes	%97
	GitHub code (researcher experiment)	No	L	No	No	No	NA

Table 2 Current model comparison

4. Limitations and Challenges in the available Research

Eye blink detection is built to serve its purpose of detecting the state of the eyes in a given situation. Previous work aims to provide a solution for reducing eye dry symptoms by building a reminder system and blinking counter. However, most available models recommend concentrating on detecting the eye blinking in the faces with sunglasses, only one eye closed, and a side view. Through the gap analysis phase, we found that no available model can detect eye blinking for ladies who were wearing Niqabs (veiled). As most of the models are either trained on not veiled faces or depend on some mathematical formal where it needs to detect the face border first and then detect the eye like (Haar cascade & Face landmark). Below are some papers mentioned related challenges:

I. Face is partially hidden (or veiled persons)

Biometric recognition based on the full face is an extensive research area. However, using only partially visible faces, such as in the case of veiled persons, is a challenging task as Macdonald, A. (2022, August 26) mentioned. A deep convolutional neural network (CNN) is used in this work to extract the features from veiled-person face images.

- ***Paper 1:*** **Eye Fatigue Prediction System Using Blink Detection Based on Eye Image**

In the Kuwahara, A., Hirakawa, R., Kawano, H., Nakashi, K., & Nakatoh, Y. (2021, January) study, they demonstrated that using OpenCV for face image normalization can improve the accuracy of blink detection in image processing. It may be due to the increase in face recognition rate by removing information other than facial expression and reducing the noise caused by face movement. The proposed system is practical for real-world product development due to its fast-processing speed using OpenCV and Dlib. On the other hand, if face recognition is not possible, detecting the blink of an eye is still impossible, so a processing method is needed to compensate for this. In the future, we would like to prepare a dataset that will detect the eye even if the face is partially hidden. In addition, we plan to build a machine learning-based eye fatigue detection system.

- ***Paper 2: Driver Eye Location and State Estimation Based on a Robust Model and Data Augmentation***

Ling, Y., Luo, R., Dong, X., & Weng, X. (2021). during the outbreak of COVID-19, recognize there are many new challenges for all walks of life. Masks are essential to protect us, especially for public transport drivers, from the risk of virus infection. However, none of the existing methods consider a large, covered area. It is difficult to precisely locate facial landmarks because of masks sheltering the face and masks' ability to reflect light at night. Increasingly more complex network structures result in high computational costs and memory capacity as well. Generally, there are two main challenges for eye location and eye state evaluation based on facial landmarks: (1) Robust landmark location performance under complicated scenarios, such as large poses, mask coverings, illumination, etc. (2) Finding a simple model network structure with low computational costs and high detection speed. Therefore, they proposed a new model using The Practical Facial Landmark Detector (PFLD) where it can identify the eyes while the driver wearing face mask (partially covered).

II. Face with sunglasses

- ***Paper1: Driver Drowsiness Detection Based on Joint Monitoring of Yawning, Blinking and Nodding***

Ghourabi, A., Ghazouani, H., & Barhoumi, W. (2020, September) proposed method has some limitations, especially when the driver has sunglasses. The writer suggests put more efforts and focused in future on how to overcome these limitations by using another classification algorithm such as convolutional neural networks and training it on a much larger training dataset.

- **Paper2: Eye blink detection using CNN to detect drowsiness level in drivers for road safety**

Vishesh, P., Raghavendra, S., Jankatti, S. K., & Rekha, V. (2021). Built a a solution by implementing the retraining of the Google MobileNetV2 model to identify eye blink where the total accuracy achieved was 97%. IIn future work, we try to concentrate on detecting the drowsiness in the faces with sunglasses, only one eye closed, and side view.

In addition, we looked into any available paper related to face or eye detection while wearing Niqab, we found some such as A Alashbi, A., Sunar, M. S., & Alqahtani, Z. (2022). proposed a deep-learning-face-detection model Niqab-Face-Detector is proposed along with context based labeling technique for detecting unconstrained veiled faces such as faces covered with niqab. This proposed model is limited to face detection where our project focusing on the eyes.

Face detection algorithms	TP	FP	FN	Accuracy	Precision	Recall
MTCNN	82	5	379	18.5%	94.2%	17.7%
Mobilenet	97	12	355	21.9%	88.9%	21.2%
Niqab-Face	261	1	179	59.1%	99.6%	59.9%

Figure 19 MobileNetV2 model comparison and outcomes

Hassanat, A. B., Albustanji, A., Tarawneh, A. S., Alrashidi, M., Alharbi, H., Alanazi, M., ... & Prasath, V. B. (2021). Proposed a deep learning based automated computer system using only partially visible faces, such as in the case of veiled persons, to identify not only persons, but also to perform recognition of gender, age, and facial expressions such as eye smile. The built dataset does not serve eye blinking requirements. However, their dataset consisit of 150 images, including 109 female and 41 male participants ranging in age from 8 to 78. we'd recommend later to collaborate to enrich the dataset for ladies wearing Niqab.

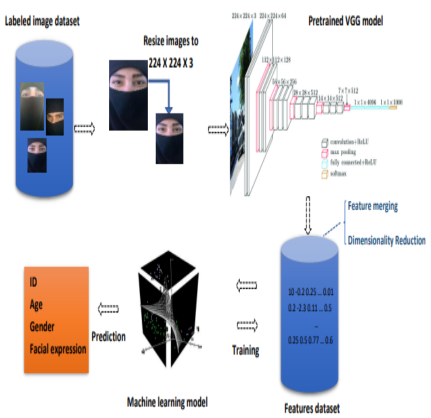


Figure 20 Veiled face detection model

Based on the experiment for all mentioned models, the best option for our proposed scope is to build a new model for eye blinking, especially for the covered face by Niqab, as they are not much effort in this field. The Haar cascade and Face landmark are required to identify the face that captures the eyes; therefore, our only option is to use CNN with a new dataset to serve project requirements. The proposed CNN model selection and implementation will be mentioned in detail in section 3.2.

3. Blinking counter & warning system

Many previous projects utilize the automation function to notify the user from any potential risk. Aravind, A., Agarwal, A., Jaiswal, A., Panjiyara, A., & Shastry, M. (2019) as example proposed a Fatigue detection system based on eye blinks of drivers where person closes his eyes for more than the minimum limit time between two blinks then an alert will be issued as shown below to the driver that he is feeling sleepy.

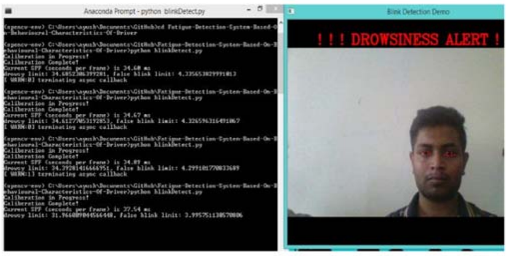


Figure 21 Blinking counter & warning system

2.2 Data privacy concerns of face data

As the solution will be on the edge, this part will discuss and review how the data be stored and processed; and if there are any concerns or risk. During the pandemic of COVID, many studies have been published, due to the increase reliability on the online services & facial recognition use cases in multiple industry such as Education, Government process, online gaming, etc. This increased use of big data and online services resulted in concerns about biometric data and where its stored. Since biometric data are highly sensitive and cannot be easily changed, there is a need for privacy-preserving solutions to avoid misuse, loss or theft. The SWAN project applies biometric template protection methods to secure biometric references stored locally on smartphone devices. This can prevent misuse of biometric data in case of data theft. Biometric template protection can also prevent linking a user's biometric characteristics between different databases (cross matching), thereby preserving the privacy of the user. In addition, the SWAN project applies novel cancellable biometric techniques (biometric template protection using Bloom Filters [29]). Cancellable biometrics provide an intentional, systematic and repeatable distortion of biometric features in order to protect user's sensitive data. For example, if a "cancellable" characteristic is stolen, the distortions provided are modified and remapped to a new template which will replace the one that has been compromised.

In general, GDPR mentioned some rules related to Biometric data, first The GDPR classifies biometric data as a type of *special* category of personal data. This means that, in principle, you may not process biometric data. However, the GDPR does allow you to process special categories of personal data if your processing falls within one of the lawful reasons for processing under the GDPR. In the other hand, some companies now moving their application from cloud to edge, by using edge computing techniques. for instance, Amazon's Alexa and Echo, a voice-controlled virtual assistant that uses ML to perform various tasks. In September 2020, Amazon released the AZ1 Neural Edge processor that would make Alexa run inferences on the device rather than interacting with the cloud. By moving computation to the edge device, Echo has been able to run twice as fast while also offering privacy benefits since the data is processed locally. And with this clear openness regulation many crucial applications in different industries have been built to help automate the work process, people monitoring or any other use cases.

The use of artificial intelligence and modern technologies will continuously increase for the society benefits. In this chapter, many similar projects/papers have been discussed, first, Introduction for monitoring system, Eye blinking application, review in most of available techniques for eye monitoring, then the data privacy on using Eye monitoring tools.

Conclusion

The use of artificial intelligence and modern technologies will continuously increase for the society benefits. In these chapters, many similar projects/papers have been discussed, first, Introduction for monitoring system, Eye blinking application, review in most of available techniques for eye monitoring and current limitations, then the data privacy on using Eye monitoring tools.

Acknowledgment

References

[1] Hassanat, A. B., Albustanji, A., Tarawneh, A. S., Alrashidi, M., Alharbi, H., Alanazi, M., ..`. & Prasath, V. B. (2021). Deep learning for identification and face, gender, expression recognition under constraints. *arXiv preprint arXiv:2111.01930*.

[2] Dementyev, A., & Holz, C. (2017). DualBlink: A Wearable Device to Continuously Detect, Track, and Actuate Blinking For Alleviating Dry Eyes and Computer Vision Syndrome. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol., 1*, 1:1-1:19.

[3] George, S., Pai, M.M., Pai, R.M., & Praharaj, S.K. (2017). Eye blink count and eye blink duration analysis for deception detection. *2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, 223-229.

[4] Macdonald, A. (2022, August 26). Deep-learning advance improves facial recognition for people wearing veils. Biometric Update |. https://www.biometricupdate.com/202208/deep-learning-advance-improves-facial-recognition-for-people-wearing-veils

[5] Phatchuay, S., Yooyen, A., & Ketcham, M. (2016). The detection eye blink on Working production line in Industrial. *2016 13th*

International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 1-5.
[6] Sikandar, T., Ghazali, K. H., Mohd, I. I., & Rabbi, M. F. (2017, July). Skin color pixel classification for face detection with hijab and niqab. In Proceedings of the International Conference on Imaging, Signal Processing and Communication (pp. 1-4).
[7] A Alashbi, A., Sunar, M. S., & Alqahtani, Z. (2022). Deep-Learning-CNN for Detecting Covered Faces with Niqab. Journal of Information Technology Management, 14(Special Issue: 5th International Conference of Reliable Information and Communication Technology (IRICT 2020)), 114-123.
[8] B. Zheng, N. J. Yuan, K. Zheng, X. Xie, S. W. Sadiq, and X. Zhou, "Approximate keyword search in semantic trajectory database," in 31st IEEE International Con- ference on Data Engineering, ICDE 2015, Seoul, South Korea, April 13-17, 2015, 2015, pp. 975–986.
[9] Cech, J., & Soukupova, T. (2016). Real-time eye blink detection using facial landmarks. Cent. Mach. Perception, Dep. Cybern. Fac. Electr. Eng. Czech Tech. Univ. Prague, 1-8.
[10] R. A. Johnson, D. W. Wichern et al., Applied multivariate statistical analysis. Prentice-Hall New Jersey, 2014, vol. 4.
[11] J. F. Hair, W. C. Black, B. J. Babin, R. E. Anderson, R. L. Tatham et al., Multivariate data analysis. Prentice hall Upper Saddle River, NJ, 1998, vol. 5, no. 3.
[12] Jebakani, S., Divya, J., Megha, S., & Santhosh, H. (2020). Eye blink to voice for paralyzed patients. International Journal of Information Technology (IJIT), 6(3).
[13] J. E. Barlett, J. W. Kotrlik, and C. C. Higgins, "Organizational research: Determin- ing appropriate sample size in survey research," Information technology, learning, and performance journal, vol. 19, no. 1, p. 43, 2001.
[14] M. S. Islam, C. Liu, and J. Li, "Efficient answering of why-not questions in similar graph matching," IEEE Trans. Knowl. Data Eng., vol. 27, no. 10, pp. 2672–2686, 2015.
[15] M. S. Islam, R. Zhou, and C. Liu, "On answering why-not questions in reverse skyline queries," in 29th IEEE International Conference on Data Engineering, ICDE 2013, Brisbane, Australia, April 8-12, 2013, 2013, pp. 973–984.
[16] Z. He and E. Lo, "Answering why-not questions on top-k queries," IEEE Trans. Knowl. Data Eng., vol. 26, no. 6, pp. 1300–1315, 2014.
[17] T. Pelkonen, S. Franklin, P. Cavallaro, Q. Huang, J. Meza, J. Teller, and K. Veer- araghavan, "Gorilla: A fast, scalable, in-memory time series database," PVLDB, vol. 8, no. 12, pp. 1816–1827, 2015.
[18] J. J. Levandoski, M. Sarwat, A. Eldawy, and M. F. Mokbel, "Lars: A location-aware recommender system," in ICDE, 2012, pp. 450–461.
[19] W. G. Aref and H. Samet, "Efficient processing of window queries in the pyramid data structure," in PODS, 1990, pp. 265–272.
[20] A. Marian, N. Bruno, and L. Gravano, "Evaluating top-k queries over web-accessible databases," ACM Trans. Database Syst., vol. 29, no. 2, pp. 319–362, 2004.
[21] R. Fagin, A. Lotem, and M. Naor, "Optimal aggregation algorithms for middleware,"
[22] J. Comput. Syst. Sci., vol. 66, no. 4, pp. 614–656, 2003.
[23] Pulli, K., Baksheev, A., Kornyakov, K., & Eruhimov, V. (2012). Real-time computer vision with OpenCV. Communications of the ACM, 55(6), 61-69.
[24] Dewi, C., Chen, R. C., Jiang, X., & Yu, H. (2022). Adjusting eye aspect ratio for strong eye blink detection based on facial landmarks. PeerJ Computer Science, 8, e943.
[25] Nguyen, N. D., Quang, N. D., Tin, D. T., & Dinh, A. (2020). Detecting and Counting Eyes Blinking Using Haar Cascade—A Handy Way to Diagnose Dry Eyes Disease. In 7th International Conference on the Development of Biomedical Engineering in Vietnam (BME7) Translational Health Science and Technology for Developing Countries 7 (pp. 447-453). Springer Singapore.
[26] Kamarudin, N., Jumadi, N. A., Mun, N. L., Keat, N. C., Ching, A. H. K., Mahmud, W. M., ... & Mahmud, F. (2019). Implementation of haar cascade classifier and eye aspect ratio for driver drowsiness detection using raspberry Pi. Universal Journal of Electrical and Electronic Engineering, 6(12), 2019.
[27] Asmara, R. A., Ridwan, M., & Budiprasetyo, G. (2021, September). Haar Cascade and Convolutional Neural Network Face Detection in Client-Side for Cloud Computing Face Recognition. In 2021 International Conference on Electrical and Information Technology (IEIT) (pp. 1-5). IEEE.
[28] Vishesh, P., Raghavendra, S., Jankatti, S. K., & Rekha, V. (2021). Eye blink detection using CNN to detect drowsiness level in drivers for road safety. Indonesian Journal of Electrical Engineering and Computer Science, 22(1), 222-231.
[29] Anas, E. R., Henriquez, P., & Matuszewski, B. J. (2017). Online Eye Status Detection in the Wild with Convolutional Neural Networks. In VISIGRAPP (6: VISAPP) (pp. 88-95).
[30] Kuwahara, A., Hirakawa, R., Kawano, H., Nakashi, K., & Nakatoh, Y. (2021, January). Eye fatigue prediction system using blink detection based on eye image. In 2021 IEEE International Conference on Consumer Electronics (ICCE) (pp. 1-3). IEEE.
[31] Ghourabi, A., Ghazouani, H., & Barhoumi, W. (2020, September). Driver drowsiness detection based on joint monitoring of yawning, blinking and nodding. In 2020 IEEE 16th International Conference on Intelligent Computer Communication and Processing (ICCP) (pp. 407-414). IEEE.
[32] Ling, Y., Luo, R., Dong, X., & Weng, X. (2021). Driver eye location and state estimation based on a robust model and data augmentation. IEEE Access, 9, 67219-67231.
[33] Kim, J. A., Sung, J. Y., & Park, S. H. (2020, November). Comparison of Faster-RCNN, YOLO, and SSD for real-time vehicle type recognition. In 2020 IEEE international conference on consumer electronics-Asia (ICCE-Asia) (pp. 1-4). IEEE.
[34] Y. Tao, X. Xiao, and J. Pei, "Efficient skyline and top-k retrieval in subspaces," IEEE Trans. Knowl. Data Eng., vol. 19, no. 8, pp. 1072–1088, 2007.
[35] I. F. Ilyas, G. Beskales, and M. A. Soliman, "A survey of top-k query processing techniques in relational database systems," ACM Comput. Surv., vol. 40, no. 4, 2008.
[36] I. Muslea, "Machine learning for online query relaxation," in KDD, 2004, pp. 246– 255.
[37] L. Pan, J. Luo, and J. Li, "Probing queries in wireless sensor networks," in ICDCS, 2008, pp. 546–553.
[38] Q. T. Tran and C.-Y. Chan, "How to conquer why-not questions," in SIGMOD Con- ference, 2010, pp. 15–26.
[39] C. Mishra and N. Koudas, "Interactive query refinement," in EDBT, 2009, pp. 862– 873.
[40] C. Mishra, N. Koudas, and C. Zuzarte, "Generating targeted queries for database testing," in SIGMOD Conference, 2008, pp. 499–510.
[41] N. Bruno, S. Chaudhuri, and D. Thomas, "Generating queries with cardinality con- straints for dbms testing," IEEE Trans. Knowl. Data Eng., vol. 18, no. 12, pp. 1721– 1725, 2006.
[42] A. Kadlag, A. V. Wanjari, J. Freire, and J. R. Haritsa, "Supporting exploratory queries in databases," in DASFAA, 2004, pp. 594–605.
[43] M. Vartak, V. Raghavan, and E. A. Rundensteiner, "Qrelx: generating meaning- ful queries that provide cardinality assurance," in SIGMOD Conference, 2010, pp. 1215–1218.
[44] N. Koudas, C. Li, A. K. H. Tung, and R. Vernica, "Relaxing join and selection queries," in VLDB, 2006, pp. 199–210.
[45] S. Chaudhuri and V. Narasayya, "Program for generating skewed data distributions for tpc-d," ftp://ftp.research.microsoft.com/users/surajitc/TPCDSkew/.
[46] K. C.-C. Chang and S. won Hwang, "Minimal probing: supporting expensive pred- icates for top-k queries," in SIGMOD Conference, 2002, pp. 346–357.
[47] M. Singh, A. Nandi, and H. V. Jagadish, "Skimmer: rapid scrolling of relational query results," in SIGMOD Conference, 2012, pp. 181– 192.

[48] A. Motro, "Vague: A user interface to relational databases that permits vague queries," ACM Trans. Inf. Syst., vol. 6, no. 3, pp. 187–214, 1988.
[49] U. Nambiar and S. Kambhampati, "Answering imprecise queries over autonomous web databases," in ICDE, 2006, p. 45.
[50] M. S. Islam, C. Liu, and R. Zhou, "A framework for query refinement with user feedback," Journal of Systems and Software, vol. 86, no. 6, pp. 1580–1595, 2013.
[51] Bouafia, Y., & Guezouli, L. (2018). An Overview of Deep Learning-Based Object Detection Methods.
[52] R. Fagin, A. Lotem, and M. Naor, "Optimal aggregation algorithms for middleware," in PODS, 2001.
[53] U. C¸ etintemel, M. Cherniack, J. DeBrabant, Y. Diao, K. Dimitriadou, A. Kalinin,
[54] O. Papaemmanouil, and S. B. Zdonik, "Query steering for interactive data explo- ration," in CIDR, 2013.
[55] A. Telang, C. Li, and S. Chakravarthy, "One size does not fit all: Toward user- and query-dependent ranking for web databases," IEEE Trans. Knowl. Data Eng., vol. 24, no. 9, pp. 1671–1685, 2012.
[56] P. E. Hart, N. J. Nilsson, and B. Raphael, "A formal basis for the heuristic deter- mination of minimum cost paths," IEEE Trans. Systems Science and Cybernetics, vol. 4, no. 2, pp. 100–107, 1968.
[57] T. Sellam and M. L. Kersten, "Meet charles, big data query advisor," in CIDR, 2013.
[58] A. Albarrak, T. Noboa, H. A. Khan, M. A. Sharaf, X. Zhou, and S. Sadiq, "Orange: Objective-aware range query refinement," in MDM, 2014.
[59] S. Chaudhuri, "Generalization and a framework for query modification," in Pro- ceedings of the Sixth International Conference on Data Engineering, February 5-9, 1990, Los Angeles, California, USA, 1990, pp. 138–145.
[60] https://datareportal.com/reports/digital-2021-saudi-arabia.
[61] Ashwini, D. L., Ramesh, S. V., Nosch, D., & Wilmot, N. (2021). Efficacy of blink software in improving the blink rate and dry eye symptoms in visual display terminal users–A single-blinded randomized control trial. Indian Journal of Ophthalmology, 69(10), 2643.
[62] Soorjoo, Martin. 2009. The Black Book of Lie Detection : Creative Commons Organization.
[63] Nugroho, R. H., Nasrun, M., & Setianingsih, C. (2017, September). Lie detector with pupil dilation and eye blinks using hough transform and frame difference method with fuzzy logic. In 2017 International Conference on Control, Electronics, Renewable Energy and Communications (ICCREC) (pp. 40-45). IEEE.
[64] George, S., Pai, M. M., Pai, R. M., & Praharaj, S. K. (2017, September). Eye blink count and eye blink duration analysis for deception detection. In 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI) (pp. 223-229). IEEE.
[65] Salehifar, H., Bayat, P., & Majd, M. A. (2019). Eye gesture blink password: a new authentication system with high memorable and maximum password length. Multimedia Tools and Applications, 78(12), 16861-16885.
[66] Phatchuay, S., Yooyen, A., & Ketcham, M. (2016, June). The detection eye blink on Working production line in Industrial. In 2016 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON) (pp. 1-5). IEEE.
[67] Wang, Y., Wang, L., Lin, S., Cong, W., Xue, J., & Ochieng, W. (2021). Effect of Working Experience on Air Traffic Controller Eye Movement. Engineering, 7(4), 488-494.
[68] Li, X., Xia, J., Cao, L., Zhang, G., & Feng, X. (2021). Driver fatigue detection based on convolutional neural network and face alignment for edge computing device. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 235(10-11), 2699-2711.
[69] Kathpal, K., Negi, S., & Sharma, S. (2021, September). iChat: Interactive Eyes for Specially Challenged People Using OpenCV Python. In 2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO) (pp. 1-5). IEEE.
[70] Guo, F., Cao, Y., Ding, Y., Liu, W., & Zhang, X. (2015). A multimodal measurement method of users' emotional experiences shopping online. Human Factors and Ergonomics in Manufacturing & Service Industries, 25(5), 585-598.
[71] Kamangar, A. (2020). A literature review of customer behaviour patterns on e-commerce websites using an eye tracker. The Marketing Review, 20(1-2), 73-91.
[72] Ishiguro, T., Suzuki, C., Nakakoji, H., Funagira, Y., & Takao, M. (2019). Immersive experience influences eye blink rate during virtual reality gaming. Polish Psychological Bulletin, 50(1)
[73] .https://www.michalsons.com/blog/biometrics-and-data-protection-law-around-the-world/42094
[74] Chen, L., Xin, G., Liu, Y., & Huang, J. (2021). Driver fatigue detection based on
[75] Aravind, A., Agarwal, A., Jaiswal, A., Panjiyara, A., & Shastry, M. (2019). Fatigue detection system based on eye blinks of drivers. Int. J. Eng. Adv. Technol, 8, 72-75.
[76] https://jmlr.org/beta/papers/v10/king09a.html
[77] https://gist.github.com/bilalkhann16/404d5a7ac7a3b73046ee74d18ec47954#file-face_eye_detection-py
[78] https://www.etutorialspoint.com/index.php/324-eye-detection-program-in-python-opencv