TASK 3: "AUTOMOTIVE LIGHTING WITH EYE GUIDANCE"

State of the art

Problematic:

The headlights of a car are the most significant asset in the car when driving by night. So far, those headlights have always been fixed and do not permit any kind of flexibility when the car is turning or when it is running in an inclined road, which increases the risk of accident occurrence by reducing the driver's visibility.

Existing solutions:

Many of the recent cars are now able to vertically adjust the headlights' direction vertically when the car is on an inclined road. However, only **Vauxhall (Opel)** has managed to implement headlights that follow the driver's vision.

Their system uses a central camera and peripheral infrared sensors that scan the driver's eyes more than 50 times per second in dusk and night-time conditions. The headlights adjust to match the driver's gaze both vertically and horizontally. Even if the driver is momentarily distracted and takes their eyes of the road, the lights will continue illuminating in the direction of travel. This will be combined with sensors outside the car that will detect daylight levels, turning on the headlights automatically when the vehicle enters a tunnel. Vauxhall said the lights will also adjust to different road and weather conditions. A forward-facing camera mounted behind the rear-view mirror can also detect the proximity of headlamps or rear lights of other vehicles. This allows the vehicle to automatically adjust the beam to preventing dazzling other users by reducing the intensity of the beam. A matrix of LEDs in the headlights additionally mean that parts of the headlight closest to oncoming traffic can be deactivated when passing other vehicles, while keeping the rest of the road illuminated.

What is Eye tracking?

The concept:

An eye tracker is a device for measuring eye activity. It describes the recording of eye position, by measuring the point of gaze (the pint where one is looking), and eye movement, by measuring the motion of an eye relative to the position of the head.

Studies of eye movements based on simple observation stretch back more than 100 years ago. In 1901, the first eye tracker was built, but could only record horizontal eye movements and required a head-mount. In the 1970's eye tracking research expanded rapidly. With technological advancements, modern eye trackers have now become less intrusive, more affordable, accessible, and experimental sessions have become increasingly comfortable and easier to set up.

The fields of application:

- To understand the connection between what we see and how we react:
    - **Visual system diagnostics:** The measurement of eye movement responses to different visual stimuli provides data for sight diagnostics.
    - **Social and cognitive psychology:** The measurement of eye movement allows deeper understanding of cognitive processes, such as attention, memory, problem solving and decision making, or social behaviours, such as schizophrenia and autism.
    - **Marketing:** Eye tracking provides crucial information about consumers' interests and behaviour. The eye tracker could be used to identify what visual elements captures the consumers attention first, which ones are totally ignored and which factors are decisive when making a purchase.
- To gain control over a device using eye movement:
    - **Rehabilitation:** People with disabilities and reduced mobility use eye tracking to control wheelchairs, robotic arms and prosthesis.
    - **Human Computer Interaction:** Eye trackers are implemented in various systems in order to enhance the user experience by allowing the user to perform certain actions remotely using eye movements.

<u>The technology:</u>

The eye tracking technology is implemented either on a distant screen or on an eye-attached device such as glasses, eye lenses or VR headsets. There are a number of methods for measuring eye movement. The most popular variant uses **video images** from which the eye position is extracted. Other methods use **search coils** or are based on the **electrooculogram**.

- **Video Images** (Pupil Centre Corneal Reflection):

Near-infrared light is directed toward the centre of the eyes (the pupils) causing visible reflections in the cornea (the outermost optical element of the eye), and this high-contrast image is tracked by a camera (or another optical sensor). Tracking where light reflects from the cornea and the centre of the pupil allows the tracking of gaze direction.

The accuracy of eye movement measurement heavily relies on a clear demarcation of the pupil and detection of corneal reflection. The visible spectrum is likely to generate uncontrolled reflections unlike illuminating the eye with infrared light as while the light directly enters the pupil, it just reflects from the iris. This means that a clear contrast is generated (with little noise) and can, therefore be followed by algorithms (running inside the eye tracker) with ease.

Bright pupil: The illumination is coaxial with the optical path and the eye acts as a retroreflector as the light reflects off the retina creating a bright pupil effect similar to red eye.

Dark pupil: The illumination source is offset from the optical path and the pupil appears dark because the retroreflection from the retina is directed away from the camera. Bright-pupil tracking creates greater iris/pupil contrast, allowing more robust eye-tracking with all iris pigmentation, and greatly reduces interference caused by eyelashes and other obscuring features. It also allows tracking in lighting conditions ranging from total darkness to very bright.

- **Search coil**:

The scleral search coil method is based on the recording of small electric currents induced by a magnetic field in a coil of very narrow-gauge wire embedded in a pliable donut-shaped plastic ring that is placed on the eye. This method is considered as the most accurate for recording eye movements, but it is an invasive technique that may cause discomfort.

- **Electrooculography**:

This method is based on a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye.

<u>Proposed solutions:</u>

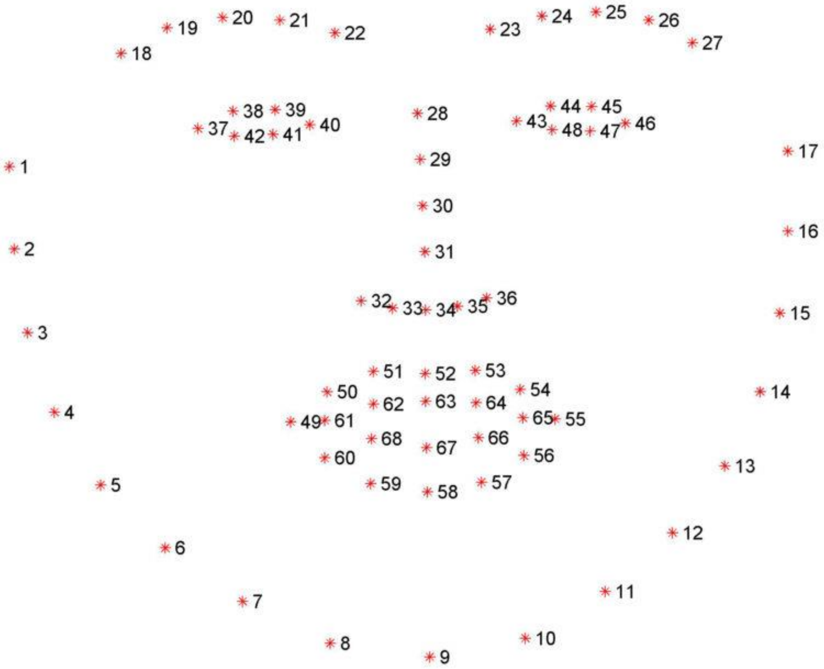
We will take inspiration from Vauxhall's system to implement one of our own. By installing an eye tracker and using its x, y coordinate output stream, we will be able to translate the movement of the eye from the eye based system to a system based on the thresholds of a car's headlight.

- **Face and eye detection :**

OpenCV offers multiple methods to detect a face or an eye from an image or from multiple frames. One of them is the use of Haar feature-based cascade classifiers, it is a machine learning based approach where a cascade function is trained from a lot of positive and negative images. It is then used to detect objects in other images, including faces and eyes, thanks to XML files implemented in the data reportory of the openCV installer.

Even though this method works, it relies principally on thresholding the white of the eyes to detect them on the face, which isn't very reliable in some circumstances, especially ours since our system is designed to be used in low lighting environments.

The facial landmark detection can also be used in our situation. The pre-trained facial landmark detector inside the dlib library is used to estimate the location of ***68 (x, y)-coordinates*** that map to facial structures on the face.



- **Pupil detection:**

The eye is composed of three main parts: Pupil : the black circle in the middle, Iris : the bigger circle whose colors may differ, and Sclera which is the white part surrounding them.

The challenge here is to identify the pupil from the rest. In order to do so, the captured images are turned gray. The pupil would generally appear darker, thus a precise threshold shall keep only the darkest pixels demarcating the pupil, and eliminate all unnecessary data.

- **Pupil movement tracking:**

A rectangle marks out the contour of the detected pupil. The variation of its center's coordinates (x,y) reflects the change in the position of the pupil. Eye tracking becomes then possible.

- **Actuators' control:**

For special eye movement angles, depending on the amplitude of the variation on either the x axis or the y axis, a horizontal or vertical direction of the lights are chosen. Otherwise, lights control directions are self-evident. It is worth mentioning that the pupil tracking tolerates a margin of error equivalent to the width and height of the detected contour.