Eyestrain-alleviating Display Adjustment

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1. Introduction

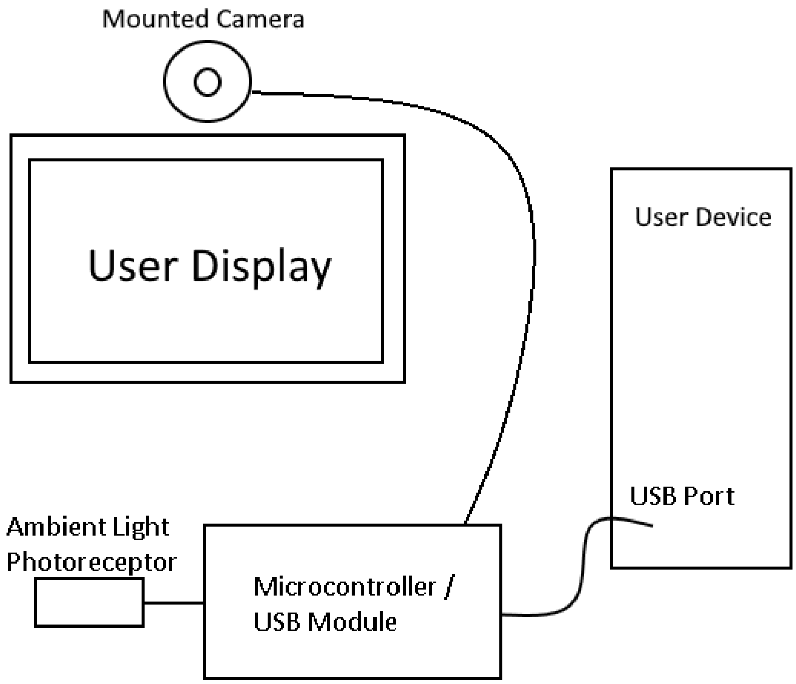
Objective and Background

Digital eye strain is a common condition that affects people who spend time using display devices. It has been shown to have multiple negative effects on vision, and most people are potentially affected by it. The primary strategy for preventing digital eye strain is prevention - adjusting the viewing environment to minimize the potential for eye strain [1].

Two symptoms associated with digital eye strain are reduced blink rate and blink completeness. These symptoms can be detected through computer vision, and serve as a sign that the current viewing environment is not healthy for the user's eyes [1]. There exist some software-only solutions that aim to detect and alleviate eye strain using this strategy, but their functionality is limited and require the user to actively work against their eye strain [2].

Our project aims to relieve eye strain from viewing devices without inconvenience to the user. We plan on taking a vision-based approach to detect eye strain through blink data, and automatically adjust the user's display. We will use a camera, ambient light photoreceptor and a microcontroller to detect and communicate potential eye strain to software on a target device, which will adjust the target device's display to accommodate the user.

Physical Design

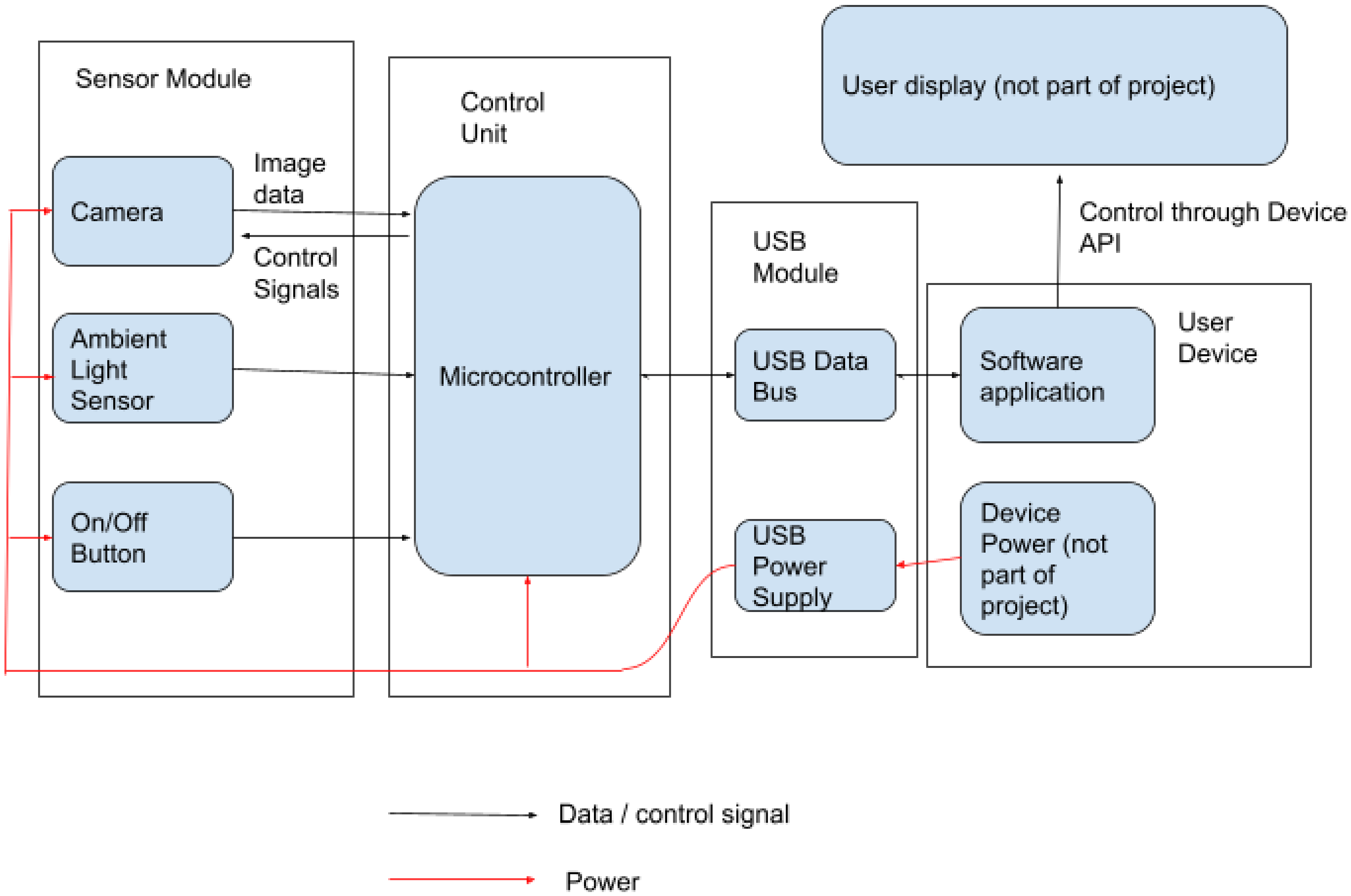


High-level requirements

1. Camera-microcontroller system should be able to capture, pre-process, and transfer image data to the USB at a rate of at least 10 frames per second.
2. Computer vision system should be able to accurately detect a blink at least 75% of the time.
3. The software application should be able to perform eye detection on 10 frames per second, without stalling or crashing.

2. Design

Block Diagram



2.1 Sensor Unit

2.1.1 Camera

The camera will capture the immediate environment and deliver captured image data to the microcontroller. It will be mounted on the user's monitor, and will be able to be manually rotated on two axes.

Requirement: The camera's resolution should be sufficiently high for our vision algorithm to detect the presence or lack of an eye in the image.
Requirement: The camera should be able to capture images at a rate of at least 10 frames per second, as a blink lasts anywhere from 100ms to 400ms [3].

2.1.2 Ambient Light Photodetector
The ambient light sensor will detect the ambient light in the environment of the user, which is a key factor in determining the brightness of the monitor. The ambient light sensor will deliver a signal indicating current light levels to the microcontroller.

Requirement: The photodetector delivers a signal readable by the microcontroller that can be consistently mapped to a digital value.

2.1.3 Power Button
This button will allow the user to disable and re-enable the system. When triggered, it will deliver a signal to the microcontroller to stop the data transfer.

Requirement: The power button should be easily accessible while being difficult to accidentally trigger.

2.2 Control Unit

2.2.1 Microcontroller
The microcontroller will be connected to the sensor unit and USB modules.

It will be programmed to receive image data from the camera, and convert the raw signals into a format compatible with the USB module's data bus. During the conversion it will also perform preprocessing operations such as compression and normalization. It will then deliver the processed image data to the USB module's data bus.

It will also send control signals to the camera module, controlling when it captures images.

Requirement: The microcontroller must be able to process each camera image before requesting the next image at a rate of 10 frames per second.

2.3 USB Module

2.3.1 Data Bus
The data bus will communicate the relevant outputs from the microcontroller to the target device via the USB data standard.

Requirement: The module must be able to continuously transfer the camera's image data at a speed of at least 2Mbps.

2.3.2 Power Supply

The power supply will draw power from the computer under the USB standard for a high-power device (5V, 500mA). The target device should already have regulated the voltage levels in its USB port.

2.4 Software Application

This app runs on the target device. It will receive a processed image from the USB module, along with the data from the ambient light sensor, and determine the level of eye strain through template matching on the presence of an eye. Once this is done, it will determine how much the display's parameters need to be adjusted to lower the eye strain, and adjust display parameters through the target device's API.

Requirement: The app must be able to process each grabbed image frame before the next frame is received at a rate of 10 frames per second, with minimal memory overhead.

2.5 Risk Analysis

A significant risk to the success of this project is the vision algorithm for detecting blink data. Developing a working computer vision algorithm is usually iterative and dependent on the images available. Being able to detect blink statistics correctly and efficiently will be difficult to achieve.

Another risk is the communication module. The image data could be very large, and needs to be transferred frequently and quickly. Being able to do so efficiently may be a difficult issue to design around. If needed, we can perform operations on the image data through the microcontroller, such as reducing bit depth. This will need to be balanced against our ability to correctly detect blink statistics with our vision algorithm.

3. Ethics and Safety

One consideration to be made is the security of the eye tracking information we collect. Given Principle 1.6 of the ACM Code of Ethics, we should respect the privacy of the user, and keep this data limited in its scope [4]. Because we are gathering image data from the user, we need to make sure that the data is only used for the purpose of checking the user's eye-strain condition and the surrounding environment. This data should be processed immediately, exclusively for our project's purpose, and immediately disposed of when no longer needed.

Another concern is adjusting the brightness of the system too rapidly. As we are adjusting the monitor settings according to the data from the sensors, there is a possibility that the brightness setting could be changed in a harmful manner. In accordance with the IEEE Code of Ethics #9, we must avoid injuring others [5]. Thus we need to ensure that the system is not too reactive, as doing so risks changing the brightness too quickly, potentially damaging the system and posing an epilepsy risk. Thus we need to limit the rate of brightness change for the system itself. We plan to limit the adjustment interval to 5-10 minutes, and limit the amount to about a 10-20% change in brightness.

Citations

[1] Coles-Brennan in Clinical and Experimental Optometry, 'Management of digital eye strain', 2019. [Online].
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