Prediction of Digital Eye Strain Due to Online Learning Based on the Number of Blinks

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ABSTRACT

Eye strain is a big concern, especially when it comes to continuous and prolonged online learning. If this is allowed to continue, it will result in Computer Vision Syndrome, also known as Digital Eye Strain (DES), which includes headaches, blurred vision, dry eyes, and even neck and shoulder pain. This condition can be observed either directly based on excessive eye blinking or indirectly based on observations of the electrical activity of eye movements or electrooculography (EOG). The observed blink signal from the EOG, as a representation of eye strain, is the focus of this study. Data acquisition was obtained using the EOG sensor and was carried out on the condition that the participants were conducting online learning activities. There are four different modes of observation taken in succession: when the eye is in a viewing state but without blinking, when the eye blinks intentionally, when the eye is closed, and finally when the eye sees naturally. Observation time is 10s, 20s and 30s, where each interval is performed three times for every mode. The obtained signal is processed by the proposed method. The resulting signal is then labeled as a Blinking signal. Determination of the number of blinks or CNT_PEAK is the result of training this signal by tunning its threshold and width. If the number of blinks is less than or more than 17 then the system will provide a prediction of eye status which is stated in two categories, the first is normal eye while the last is eye strain or fatigue.

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1. INTRODUCTION

The COVID-19 pandemic, which has lasted almost two years, has had a major impact on education. The teaching and learning process which is actually carried out face to face or offline is forced to be carried out online. Without specific guidelines, it is now a regular routine for students to spend most of their time (8–12 hours per day) attending lectures online, in front of digital devices such as computers or cell phones.

Online learning has positive things, for example, lectures are not limited by space and time, but of course there are also negative things, especially in the form of complaints in the eyes due to being in front of the monitor for too long. This eye complaint is known as eye strain, where viewing a computer screen is different from reading a printed page. Often the letters on a computer screen are inaccurate or not sharply defined, the contrast of the letters to the background is reduced, and the presence of glare and reflections on the screen can make viewing difficult [1]. This condition can eventually have an impact on eye health, namely Computer Vision Syndrome (CVS), including tired eyes, dry eyes, headache effects, blurred vision, and even neck and shoulder pain [2].

CVS or also known as Digital Eye Strain (DES) is a public health threat that appears and is directly proportional to the duration of exposure to digital screens. In the modern era, the use of digital screens is quite common among the general public and students, especially in this case. However, the impetus of unlimited online learning puts a strain on their already overburdened eyes. And in this way unwittingly, we push them into higher DES risk [3].

Observations of DES can be done either directly by looking at how often the eyes blink or indirectly by looking at the electrical activity of eye movements in the form of Electrooculography (EOG) bio signals. EOG is a bio signal due to electrical activity that occurs on the surface of the skin around the eyes [2], has an amplitude of 15-200uV, and its relation to eye movement is linear and the waveform is easily detected. The eye movement is collected using the EOG sensor. This is due to the real-time recording of the EOG signal, which allows for the correct observation response according to the online learning timeframe. Unfortunately, the EOG has major issues in terms of potential aberrations and eye blinking. However, it can be solved with the use of adequate signal processing [2].

Generally, eye movement research is used to make applications for controls such as cursors, DC motors [4], wheelchairs [5]–[7], and security systems [8]. These studies tend to ignore the risks of DES to the eyes if used actively for interaction with monitor-based devices [9]. Whereas from a medical point of view, eye movements such as blinking can be used to detect fatigue or eye strain, which are usually processed by the image processing method [10]-[11]. Relaxed people blink about 15–20 times per minute [12].

However, in previous studies related to DES, the detection of this syndrome was concluded based on the results with questionnaires distributed to subjects [13]-[14]. In addition to using a questionnaire, this syndrome can also be identified and measured objectively, by directly observing eye blinks and reading the EOG chart [10]-[11], [15]–[17]. Moreover, the blink characteristic for example reduction in blink rate, due to frequent computer use, is increasingly being used as a measurement parameter in recent DES studies [18] and it is considered relevant to the symptoms associated with DES [19]. Based on this, this research proposes a method of predicting eye strain based on EOG signals automatically. The observed cases were online learning, especially during the Covid-19 pandemic.

To produce high performance in EOG signal pattern recognition, various techniques have been proposed in previous research, including pre-processing with wavelet denoising [3], derivative techniques [4], and slope analysis techniques. Then the next required component is feature extraction [3]. However, in this study related to the detection of eye movements, namely the number of blinks which is a representation or parameter of eye strain and is the focus of this research, a new method is proposed that adopts the working principle of comparison using the expert system method [20].

2. RESEARCH METHOD

Blink rate, as one of the parameters in the objective measurement of the indices of visual fatigue in the DES case [18], thus become the focus in this study. The blink, is acquired using the BITalino assembled EOG sensor which is designed for eye movements activity measurement [21]. The EOG sensor and its example readout is show in Figure 1.

2.1. Experiment Setup

The data acquisition process involved 10 participants, whom from each of them informed consent was obtained. This process is carried out on the condition that the subject is conducting online learning activities. The experimental setup and experimental flow block diagram are illustrated as seen in Figure 2 dan Figure 3. Each EOG data retrieval from participants is carried out with four different observation modes sequentially. The four modes are:

- at first, the eyes are in a state of seeing but without blinking,
- secondly, the eyes are blinking intentionally,
- thirdly, the eyes are closed,
- finally, the eyes are seeing normally.

These modes are observed with time intervals of 10s, 20s and 30s, where each interval is taken place three times for every mode. The total observations of each mode for each participant are stored in a separate file. So, in total there are 40 raw data files. In addition, the light intensity of the surrounding is also measured at the beginning of each data acquisition.

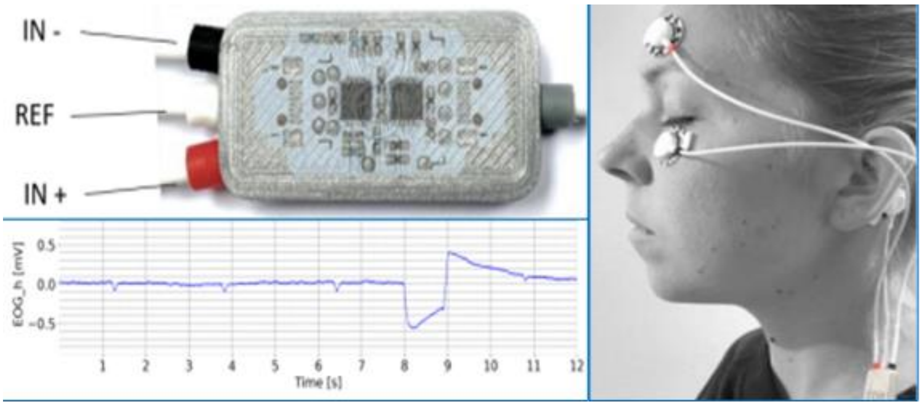


Figure 1. BITalino EOG sensor with its 3 electrodes pin connections IN-, REF, and IN+(up-left), example of EOG signal (below-left) with eye movement where eye blinking are positive / negative peaks, Electrode Positioning (right) where IN+ above and IN- below one eye and REF behind the ear [21].

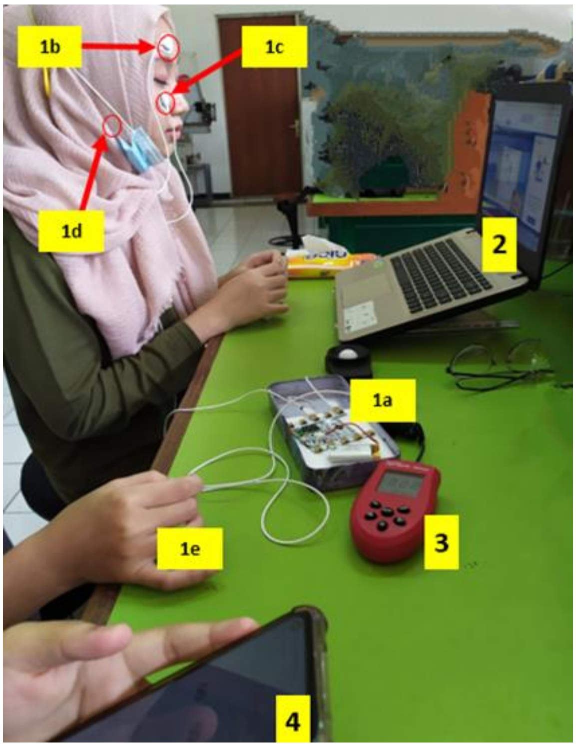


Figure 2. Example of experiment setup for eyes close mode.

Experimental devices are 1a: EOG sensor, 1b - 1d: EOG electrodes, 1e: pushbutton as marker “value of 1”, 2: laptop as e-learning media, 3: flux meter, and 4: smartphone use as time keeper

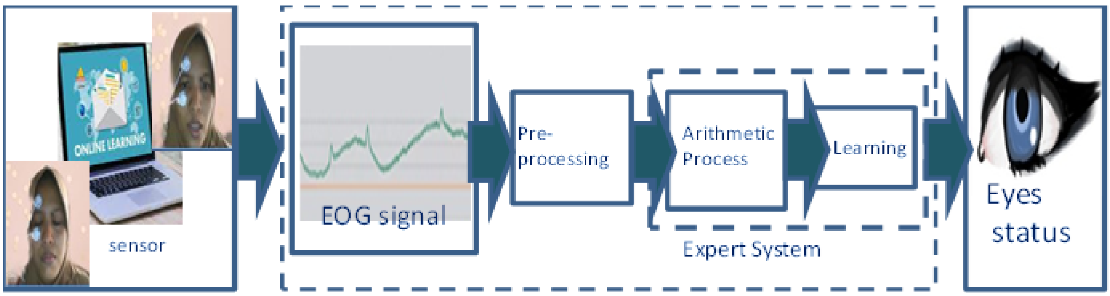


Figure 3. Experiment Flow Block Diagram

2.2. Determination of Blinks

Blinking, which is not recorded via camera, can be determined when there is a minimum change in the voltage of the observed signal within a period of time as studies [22]–[27] suggested. Further, in this research, to determine the number of blinks, data is processed using a notebook with hardware specification of Processor AMD Ryzen 7 4800H (16 CPUs), 2.9GHz, Memory 8 GB. Graphical AMD Radeon 400MHz runs two applications which are OpenSignal, the default application of BITalino EOG sensor, and visual-based programming language. Figure 4 is an example of a graphical display of the results of EOG data acquisition with OpenSignal.

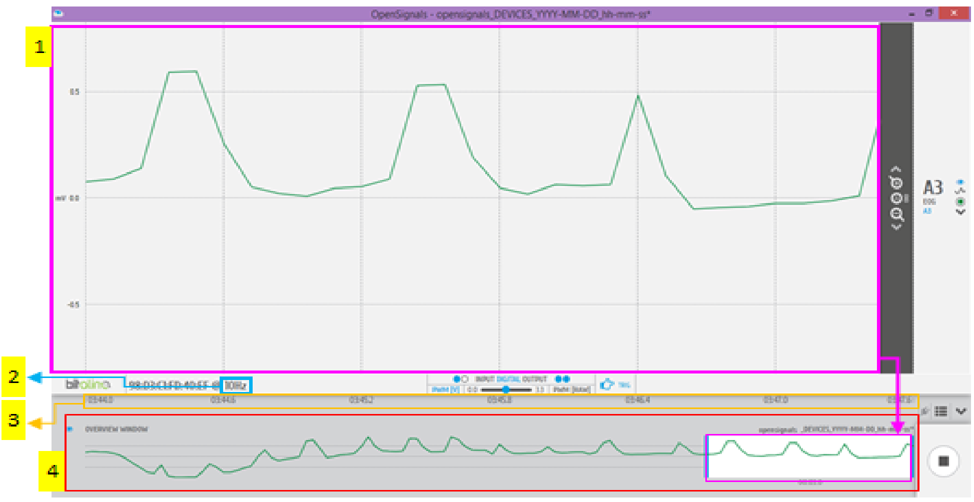


Figure 4. Example of EOG data acquisition result with OpenSignal of signal mode-2 (intentional blinking). (1): zoom in on signal, where axis y is amplitude(mV) and axis x is time (s); (2): sample rate of datalogger where 10 data are acquired in 1 second; (3): shows the timing when the app is running; (4): real time signal

The determination of blink is conducted in several stages. First of all is the process of matching filtering raw data for any observation mode. In this process the data is sorted from the raw data based on the recorded logical value of 1, represented in the form of pressing the pushbutton on EOG sensor. The logical '1' is described as a label which tell that data acquisition process is in progress. This process is referred to as "match filter raw data". Second, is the labeling stage. Here, the signals are labeled as s(n), t(n) and m(n) where:

- s(n) : normal signal or signal sample to be processed as many as n samples
- t(n) : sample signal of the first mode signal, the condition in which the eye sees without blinking, as many as n samples
- m(n) : sample signal from the third mode signal, eyes are closed, as many as n samples.

Then, arithmetical, comparison-like process [20], is applied among those signals as shown in Figure 5. The equation is as follow:

$$a(n) = t(n) + m(n) \quad (1)$$

$$b(n) = s(n) - a(n) \quad (2)$$

$$e(n) \approx b(n) \quad (3)$$

where:

a(n) is eyes-squinting signal: a calculated signal between two signal modes: the signal mode where the eyes see without blinking and where the eyes are closed;
b(n) is comparison signal; and
e(n) is blinking signal: a replica of the squinting signals whose width and threshold have been observed.

After the above process is done, then the next stage is detecting and counting the peaks of blinking signal. It is done in order to determine and get the number of blinks. The results that is obtained here are then used as parameters to predict the condition or status of the eyes related to DES whether they are normal or not

[18], [28]. Figure 6 describes the flow of the process of blink counting and its relation to eyes status. As a realization of the proposed method, the Human Machine Interface (HMI) is developed as seen in Figure 7.

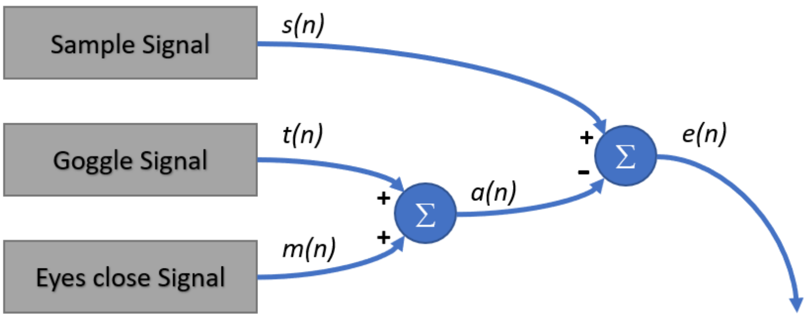


Figure 5. The equation signals.

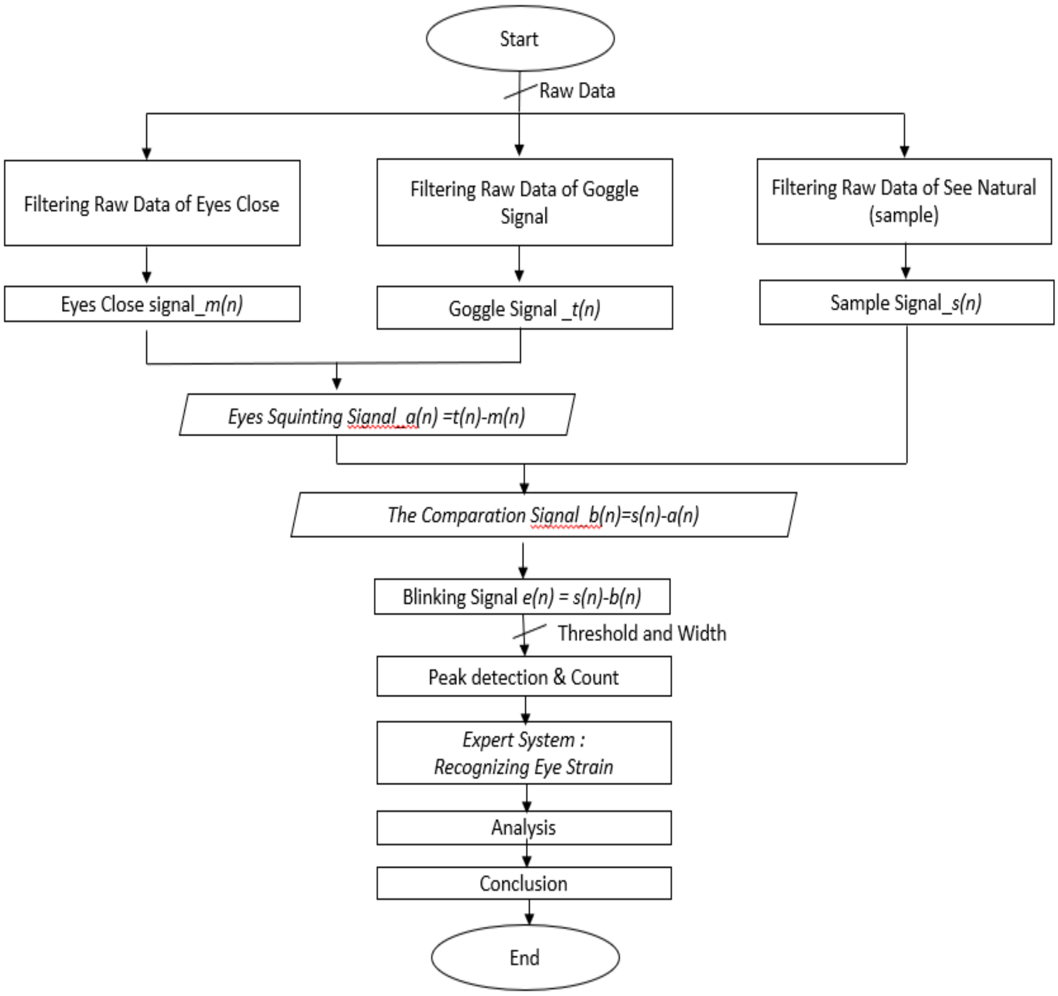


Figure 6. The flow of the process of blink counting and its relation to eyes status

As a realization of the proposed method, the Human Machine Interface (HMI) is developed as seen in Figure 7.

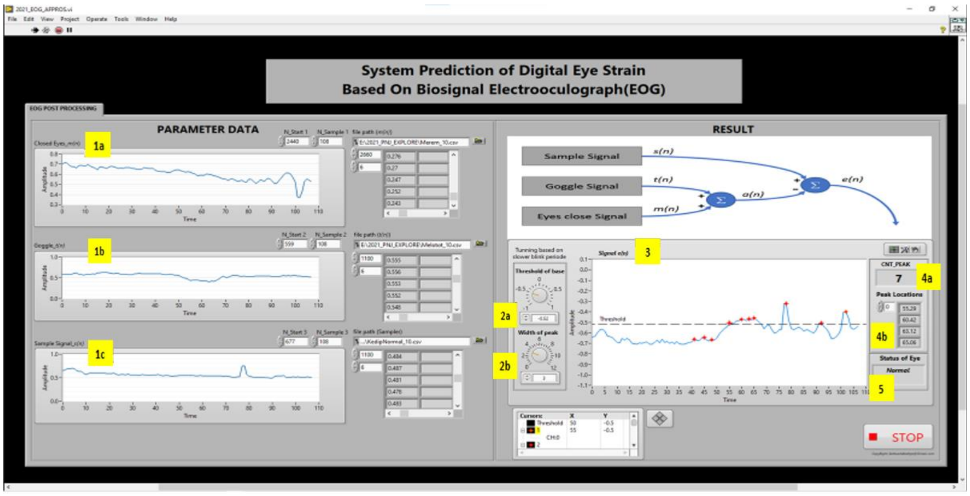


Figure 7. HMI Digital Eye Strain Prediction.
EOG mode-3 (1a), mode-2(1b) and mode-4 (1c); Tuning knob for threshold (2a) and width (2b); Result: Blinking signal (3), Blink's determination is represented as Count / Number of Blink (4a) and Location of Peak (4b), and finally Eye Status using expert system (5).

The HMI of fatigue prediction as shown in Figure 7 consist of data parameter and result test as prediction. Data parameter consist of three mode that are close eyes signal, google signal and sample signal from participants. The sample signal will determine the threshold of base and signal width of peak for prediction on each sample.

3. RESULTS AND DISCUSSION

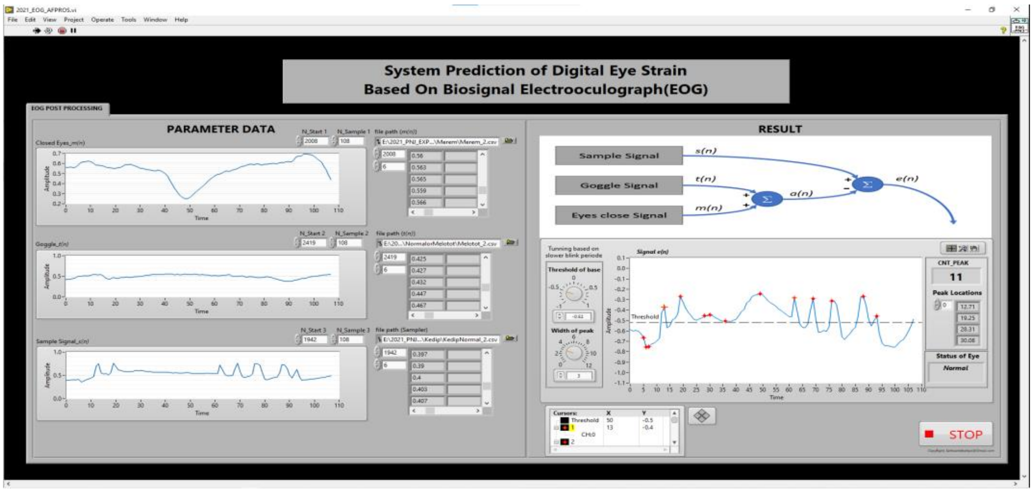
As mentioned at the beginning of this paper, there are many aspects to determine whether the eye is strained or not. However, in this research the prediction of determining that eye status is simplified. What is meant by simplification is that eye strain is defined as the number of blinks of EOG signal within time of observation. The application that has been developed appropriately worked to detect and count the number of blinks of the acquired EOG signal.

In this study, eye fatigue prediction is based on CN PEAK where CN peak is the peak period in unit time. The period in pulses is the response signal from the EOG. Observation time is 10s, 20s and 30s, where each interval is performed three times for every mode. The obtained signal is processed by the proposed method, a process such as comparison. The resulting signal is then labeled as a Blinking signal. Determination of the number of blinks or CNT_PEAK is the result of training this signal by tunning its threshold and width. If the number of blinks is less than or more than 17 then the system will provide a prediction of eye status which is stated in two categories, the first is normal eye while the last is eye strain or fatigue. This value is based on the results of interviews with ophthalmologists as expert judges. In addition, it is in accordance with the results of previous studies which suggested that 12 blinks per minute [29] or else higher than 24.8 blinks per minute [30] is considered normal [27].

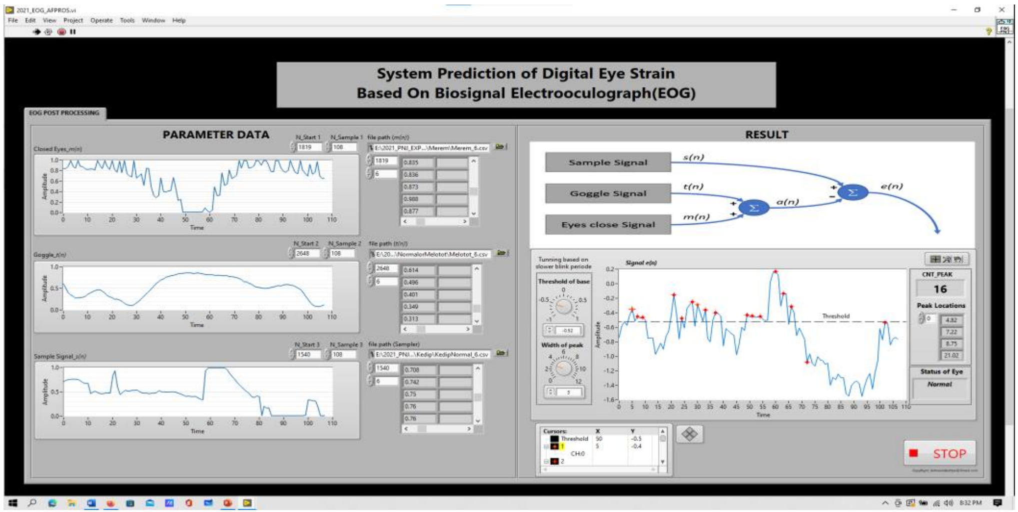
For the validation of the results, four participants' EOG data are chosen and their eyes status are predicted. These four are selected because of the result from the pre-observation survey which is included in the Informed Consent form. It stated that they all have eye problems related to the eye strain symptoms. The predictions of their eye status are shown in Figure 8a to Figure 8d and the results are "Normal" for all. As can be seen from these pictures, the EOG signal even though the modes are the same but for each person the graph is totally different and not stable. This could be due to two main things:

1. Standard Operation Procedure for data collection:
   For example, when data mode 3 (eyes closed) is collected. If the participant is calm, the results will be seen by direct observation of the signal pattern. The opposite will happen if the participant is affected by the surrounding conditions such as smiling or even laughing.
2. the instrument is less stable.

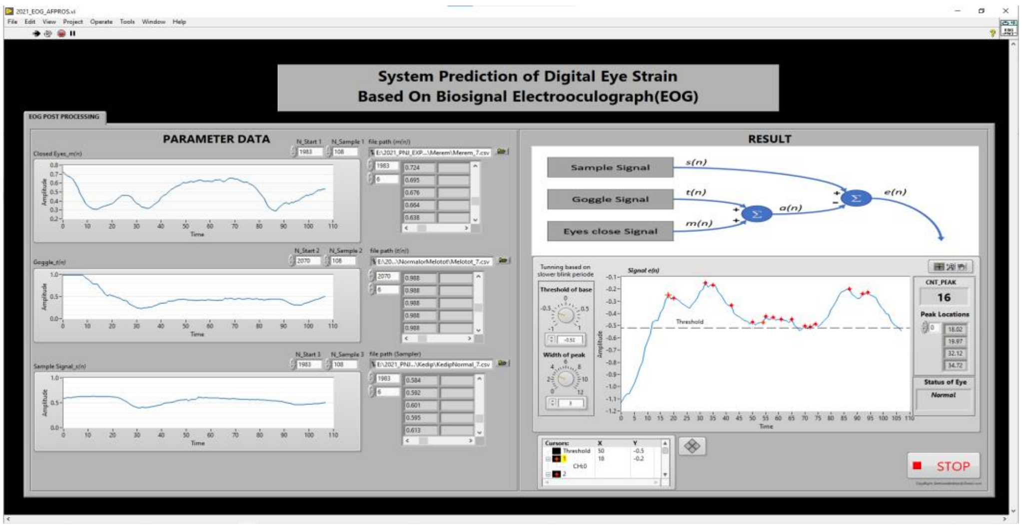
For example, the graphical appearance of the data looks messy. Besides that, there is a lack of information regarding how to read and to interpret the measured EOG signal.


System Prediction of Digital Eye Strain
Based On Biosignal Electrooculograph(EOG)
EOG POST PROCESSING
PARAMETER DATA
RESULT
Sample Signal
Goggle Signal
Eyes close Signal
CNT_PEAK
11
Peak Locations
Status of Eye
Normal
STOP

(a)


System Prediction of Digital Eye Strain
Based On Biosignal Electrooculograph(EOG)
EOG POST PROCESSING
PARAMETER DATA
RESULT
Sample Signal
Goggle Signal
Eyes close Signal
CNT_PEAK
16
Peak Locations
Status of Eye
Normal
STOP

(b)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Peak Locations
Status of Eye
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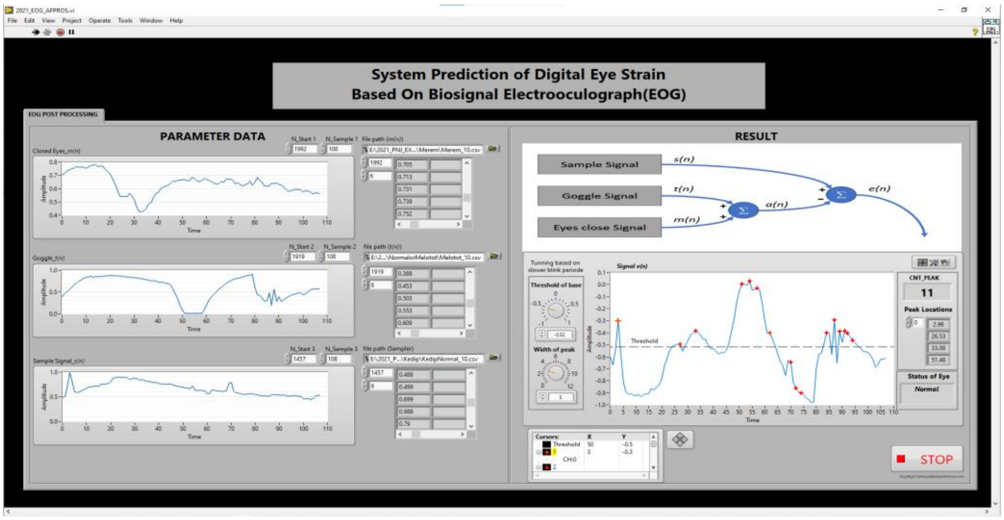
STOP

(c)



(d)

Figure 8. EOG of participant-2(a), participant-6(b), participant-7(c), and participant-10(d).

Furthermore, although the results obtained are not consistent, as seen in the case of participants10 in Figure 9, it can be considered that the results of the research related to the system developed especially for the search feature and peak calculation, which is a way to count the number of blinks, gives a logical predictive result of eye status. The logic here means that if the number of blinks is less than or equal to 17 then the eye is predicted to be normal, whereas if it is more than 17 then the eye is declared eye strain or fatigue.

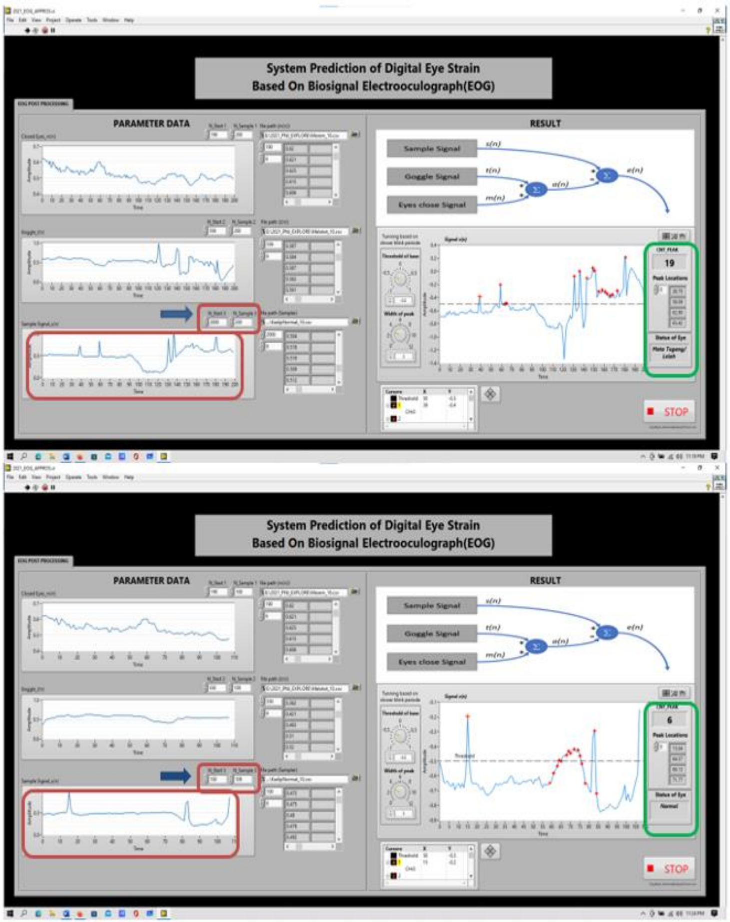


Figure 9. Checking feature. The arrow points to the control or selector of n samples.
If this selector is set to a different value, the graphical display of the signal (red box) will be affected, and will directly affect the prediction result (green box).

The prediction system is processed by using expert system based on CNT_peak. CNT_peak is obtained from the number of periods generated based on the threshold and width. Width is obtained from the width of the signal per unit time when there is a flicker of the participant. while the threshold is the amplitude of the obtained signal [27]. In this case, the amplitude value is obtained from the sensor voltage value.

So, it is possible that everyone has a different threshold and width because everyone's blinking speed is different. In addition, as suggested from the previous study, threshold parameters can be determined in the presence of positive and negative blink strength thresholds [31]. Here, the positive threshold is obtained from the positive max peak value and the negative threshold is obtained from the negative min peak value. Meanwhile, in this research, the positive threshold parameter was obtained from the Goggle Eyes Signal data value (Figure 7-label 1b) and the negative threshold was obtained from the Eyes Close Signal data value (Figure 7-label 1a). Then, only one threshold value was used, the baseline values for Goggle Eyes and Eyes Close signals (Figure 7-label 2a).

4. CONCLUSION

The proposed method is suitable to be applied because everyone has a different eyes-squinting signal and it is impossible to create a generalized base signal for everyone. System can predict the eyes status become two categories that are normal eyes or fatigue eyes. Therefore, in the future, it is necessary to collect baseline data from samples of closed-eye and unblinking modes from each participant. In addition, the feature of Blink Counter in the HMI application is able to detect and count the number of blinks of the acquired EOG signal, which is an indicator of eye strain. Furthermore, the usefulness of this application can be embedded in the Learning Management System (LMS) as an early warning of Digital Eye Strain for both students and lecturers/teachers when conducting online learning.

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