Real Time Drowsiness Detection using Eye Blink Monitoring

Amna Rahman
Department of Software Engineering
Fatima Jinnah Women University
Rawalpindi, Pakistan
amnarahman24@yahoo.com

Mehreen Sirshar
Department of Software Engineering
Fatima Jinnah Women University
Rawalpindi, Pakistan
msirshar@gmail.com

Aliya Khan
Department of Software Engineering
Fatima Jinnah Women University
Rawalpindi, Pakistan
Aliya.fjwu@gmail.com

***Abstract*— According to analysis reports on road accidents of recent years, it's renowned that the main cause of road accidents resulting in deaths, severe injuries and monetary losses, is due to a drowsy or a sleepy driver. Drowsy state may be caused by lack of sleep, medication, drugs or driving continuously for long time period. An increase rate of roadside accidents caused due to drowsiness during driving indicates a need of a system that detects such state of a driver and alerts him prior to the occurrence of any accident. During the recent years, many researchers have shown interest in drowsiness detection. Their approaches basically monitor either physiological or behavioral characteristics related to the driver or the measures related to the vehicle being used. A literature survey summarizing some of the recent techniques proposed in this area is provided. To deal with this problem we propose an eye blink monitoring algorithm that uses eye feature points to determine the open or closed state of the eye and activate an alarm if the driver is drowsy. Detailed experimental findings are also presented to highlight the strengths and weaknesses of our technique. An accuracy of 94% has been recorded for the proposed methodology.**

***Index Terms*—drowsiness detection, eye blinks detection, eye tracking, eye monitoring.**

I. Introduction

The word “drowsy” means “sleepy” that is, having a tendency to fall asleep. Drowsiness usually occurs due to insufficient sleep, variety of medications, and also due to boredom caused by driving vehicles for long periods of time. In a drowsiness state, a driver will lose control of his vehicle resulting in an accident. According to statistical reports, every year, more than 1.3 million people die in road accidents and 20 to 50 million people bear severe injuries and disabilities because of road side accidents [1]. To alleviate this problem and to avoid these destructive mishaps, the state of driver needs to be constantly under observation.

The measures that have been employed for drowsiness detection falls into three basic categories: physiological, behavioral and vehicle based measures. The algorithm proposed in this paper utilizes the ‘behavioral’ measure of the driver, that is, it works by interpreting the visual signs of the driver.

The paper is organized as follows: Section 2 presents a literature survey which discusses previous drowsiness detection methodologies presented by different researchers, their strengths and weaknesses in detail. Section 3 discusses the proposed technique in detail. Section 4 describes the results and analysis. Section 5 presents the future work and concludes the paper.

II. Literature Survey

In this section, we discuss various methodologies that have been proposed by researchers for drowsiness detection and blink detection during the recent years. Strengths and weaknesses have been identified for each technique and suggestions are given for their improvement in future.

Mandeep and Gagandeep [2] in 2012, proposed a method that detects drowsiness using the mean sift algorithm. It perform real time eye blinks detection using a webcam in 640x480 resolution. Eyes are detected from each frame and each eye blink is measured against a mean value. The system compares the eye opening at each blink with a standard mean value and an alarm is triggered if the eye opening exceeds this value for a certain amount of consecutive frames. The authors have recorded an accuracy of 99%. In addition, it runs at a 640×480 resolution that is valid for real-time circumstances. In this algorithm, the system has to retain information about the past frames because the eye blinking measurements from a collective amount of frames are used to monitor drowsiness.

Vitabile et al [3], in 2011 presented a real time drowsiness detector to be used in vehicles. An 850nm infrared light source is fixed on the car dashboard causing a bright pupil effect. This makes eye detection easier as the eye’s retina has a property of reflecting 90% of the light incident on it. Drowsiness state is identified when the eyes are more than 80% closed for a certain period of time. Efficient image processing techniques are combined with established hardware technology like Field Programmable Gate Array (FPGA). This permits real time drowsiness detection and enable the system to process an entire 720x576 frame in 16.7 microseconds. FGPA's scalability and code reuse may help to cut down the costs of development. Some false detection has been observed during experiments in the presence of eyesight glasses or the objects reflecting the infrared rays. Further work is required to overcome the limitations in eye detection of glasses wearers to make it available for all type of drivers and enabling the system to support infrared reflecting objects.

Flores et al [4], in 2009, presented a component for Advanced Driver Assistance System (ADAS) to automatically detect drowsiness. The module uses artificial intelligence algorithms along with the visual data being captured. The system identifies and monitors the face and eyes and determines drowsiness using support vector machines (SVMs). The system is designed to work under changeable light conditions in real time. This system works by taking into account further other distractions of the driver apart from eye blinking i.e. yawning, head tilt and face orientation are also monitored to detect drowsiness which makes the system highly reliable. Limitation of the proposed system is that the results show some percentage error which means that the system may cause some unexpected false alarms. In future main focus shall be to decreases the false alarms. For achieving this more tests should be conducted, with different drivers and by integrating new modules.

Chuang-Wen et al [5], in 2013 introduced "CarSafe", the first android smart phone application for drowsiness detection. The application requires a dual camera Smartphone and operates by switching between two camera pipelines. The front camera pipelines monitors the driver's eye blinks rate and head pose to determine drowsiness. Back camera takes the vehicle based measures into account. It determines the vehicle's distance with other vehicles on the road to check if driver is close to other vehicles as well as check the lane change situation. Carsafe has an 83% precision and 75% recall.

Sahayadhas et al [6], in 2013 used EOG (Electroculogram-signal that measures cornea-retina potential difference) to monitor eye movements. The readings are then used to detect driver's drowsiness. The researchers have exploited physiological signal based measures to detect drowsiness which are more accurate and reliable as they use information about the internal state of the driver. There are various other physiological measures e.g. EEG (Electroencephalography), ECG (Electrocardiography), EMG (Electromyography) which could also be used to improve efficiency of the system. In the future ECG (Electrocardiography-detecting heart signals) and EMG (Electromyography-studying muscle activity) signals can be combined with the vision based measures for more accuracy in making decision about the driver's state.

III. Methodology

Fig.1 shows an abstract level flowchart of the proposed methodology.

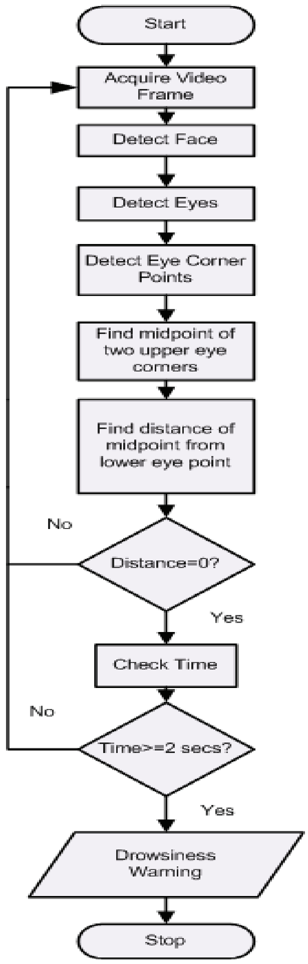

Fig. 1. Flowchart for Proposed Algorithm

An outline of the algorithm is provided below:
Step 1: Acquire video frame from the capturing device.
Step 2: Detect face.
Step 3: Detect and crop the eye region.
Step 4: Find the two eye corners and one point on the lower eye lid. (Fig. 2 shows the required eye points).
Step 5: Find midpoint of the two upper eye corners and find its distance from the lower eye lid point.
Step 6: If the distance is zero or near to zero, the eye state is classified as "closed".
Step 7: If the eye state is "closed" constantly for 2 or more seconds, the driver is assumed to be drowsy and an alarm is triggered.

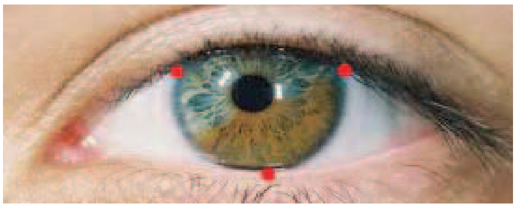

Fig. 2. Required Eye Points. Eye Image [9]

In this section, each step of the proposed technique is discussed in detail.

A. Face Detection

First step of the algorithm is to extract the face region from the input video frame. For this purpose the Viola Jones [7] algorithm has been used. Paul Viola and Mike Jones, in 2001, presented the first ever real time face detector. This algorithm classifies images on the basis of values of simple features [7]. Its main benefits are speed and accuracy, as it achieves detection rates comparable to best systems and is much faster than the most of them. A distinctive quality of this algorithm is that it uses rectangular features instead of individual pixels. At first, sum of pixels is calculated within a rectangular box. Combination of box sums form features. Fig. 3 shows rectangle features with respect to the enclosed detection window. Two rectangle features are shown in (A) and (B) while (C) and (D) shows three and four rectangle features respectively [7].

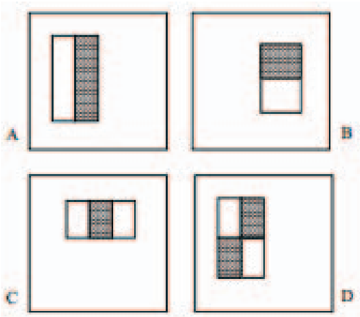

Fig. 3. Rectangle features relative to the enclosing detection window[7]

To compute these rectangle features rapidly and faster, Viola and Jones introduced a representation of the image called integral image. They demonstrated that using this integral image, four array references can be used to compute any rectangular sum. The task of preparing the classifier to select the best feature from the all the features uses the characteristics chosen by Adaboost[7]. Adaboost is a computational approach that finds a single rectangle feature using a weak learning algorithm. The weak learner finds out the best threshold classification function for each feature, such that there is least misclassification of examples. Most of the area, in an image, is non-face region. Hence the better idea would be to discard a region if it is not a face region, and do not process it again. In this way, more time is left to look for a possible face region. Viola and Jones established the idea of **"**Cascade of Classifiers" to carry out this mechanism**.** In this method, the features are classified into various steps of classifier. Each feature is applied one at a time, instead of applying all 6000 on a single window. If a window does not pass the first phase of features it is rejected and all other features on it are also discarded. If it passes, the second stage is applied to the window and the method continues. The window that successfully passes through all these stages is selected as face area. This is diagrammatically illustrated in Fig. 4[7].

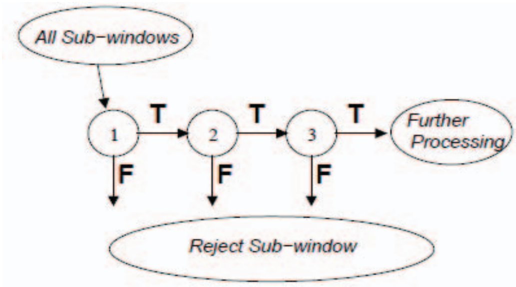

Fig. 4. Cascade of Classifiers [7]

By applying the Viola Jones algorithm we successfully detected the face region from the video. Fig. 5 demonstrates the results.

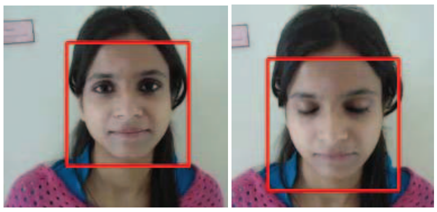

Fig. 5. (a) Normal Position (b) Downward Orientation

B. Eye Detection

Once the face is identified, the Region of Interest (ROI) is set to the face rectangle, detected by the Viola Jones algorithm. On this region again the Viola Jones Cascade classifier is applied to detect eyes. Viola and Jones introduced Haar like features for eye detection [8] which are shown in Fig. 6.

Fig. 6. New Features added to the Viola and Jones paper for eye detection[8]

A haar cascade classifier is again applied that uses these features (see Figure 6) to detect the eye region. Both eye regions are then extracted for further processing. Applying Viola Jones Classifier for eyes detection gives the results as illustrated in Fig. 7 (a) and (b).

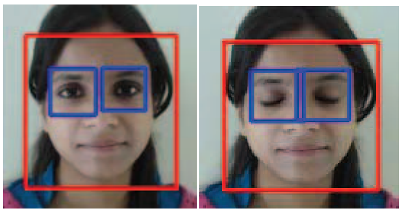

Fig. 7. (a) Open Eyes (b) Closed Eyes

C. Eye Blink Detection

In this section, a step wise description of the proposed blink detection technique is presented along with the experimental results of each step.

1) Grayscale Conversion

The colored eye image is first converted to grayscale. Gray scale conversion algorithms use the following three steps to convert color image to grayscale.

1. Take green "G", red "R" and blue "B" values of image pixels.
2. Use any formula method to convert those RGB values into one gray value.
3. New grayscale value replaces original RGB value of image pixel.

For grayscale conversion "Luminosity Algorithm" [9] has been used. The luminosity first averages the R, G, B values of a pixel. This is given as:

$$(R + G + B) / 3 \qquad (1)$$

Then it forms a weighted average to deal with human sensitivity [9]. Green is weighted most heavily as human eye is more sensitive to this color.
The formula for luminosity is

$$0.72\,G + 0.21\,R + 0.07\,B \qquad (2)$$

The computed value is replaced with the original value of the pixel. Results of applying the Luminosity Formula to the eye region are shown in Fig. 8.

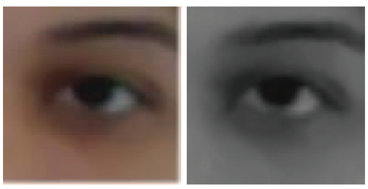

Fig. 8. Eye Image (a) Colored Image (b) Grayscale Image

2) Corner Detection

Corners are defined as intersection of two edges. We propose an eye blink detection algorithm that uses the two eye corner points and one point at the lower eye lid. To detect these points, Harris Corner Detector has been used. The reason for using Harris Corner Detector is one of the most used corner and interest point detector and is invariant to illumination variation, image noise, scale and rotation. Harris Detector calculates difference of the corner on the basis of direction directly [11]. It uses a mathematical approach to determine which case holds for a given point from the following possible cases [11]:

1. flat region implies that there is no change in any direction
2. edge implies that there is no change along the edge direction
3. corner implies a significant change in all directions

This corner detector makes use of the fact that a corner is simply the point where two edges intersect. In other words it is the point at which the two edges change direction. The image gradient has an increased variation in both directions, which can be used to detect it. This "variation" is determined by Harris Corner Detector. On applying the Harris Corner Detector on the input eye image we get the points as indicated in Fig. 9.

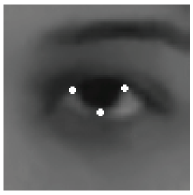

Fig. 9. Corner points after applying Harris Corner Detector

3) Midpoint Calculation

A midpoint is defined as the middle or center point of a line segment[12]. Once all the required points have been found, the next step would be to find midpoint between the two upper corner points.

Let (x_1, y_1) be the coordinates of upper left corner and (x_2, y_2) be the coordinates of the upper right corner. A line segment is drawn between these two points. The midpoint of this line segment can be calculated using the following formula [12]:

$$\left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right) \qquad (3)$$

Fig. 10 (a) shows the line segment drawn between the two points. (b) Illustrates the midpoint of the line segment.

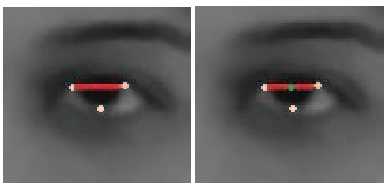

Fig. 10. (a) Line Segment drawn between two upper corner points. (b) Midpoint between the corner points shown in green.

4) Distance Calculation

Distance is a mathematical description of how far objects are from each other. As next step, we find distance of the midpoint from the point at lower eyelid. In analytic geometry, distance between two or more points is calculated by using the distance formula given by the Pythagorean Theorem[13]. The distance between two points (x_1, y_1) and (x_2, y_2) is given as:

$$d = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}. \qquad (4)$$

Fig. 11 illustrates the line segment that joins the midpoint to the point at the lower eyelid.

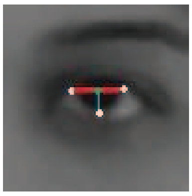

Fig. 11. Line segment that joins mid point to the point at the lower eyelid

5) Eye State Determination

Finally the decision for the eye state is made on the basis of distance 'd' calculated in the previous step. If the distance is zero or is close to zero, the eye state is classified as "closed" otherwise the eye state is identified as "open". The results are illustrated in Fig. 12 (a) and (b).

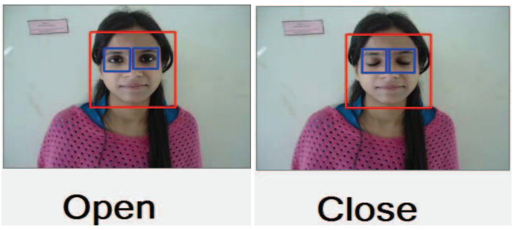

Fig. 12. Blink Detection Results (a) Eyes Open (b) Eyes Closed

D. Drowsiness Detection

The last step of the algorithm is to determine the driver's condition on the basis of a preset condition for drowsiness. The average blink duration of a person is 100-400 milliseconds [14]. This is 0.1-0.4 of a second. Hence if a person is drowsy his eye closure must be beyond this interval. We set a time frame of two seconds. If the eyes remain closed for two or more seconds, an alarm is triggered alerting the driver. Fig. 13 shows the drowsiness warning.

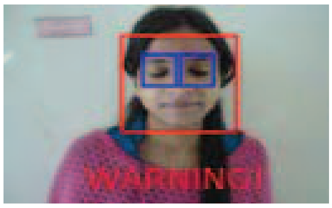

Fig. 13. Drowsiness Warning

TABLE I. RESULTS

No.	Evaluation Parameters				
	Camera Resolution (MP)	*Lighting Conditions*	*Missed Detections*	*Positive Detections*	*Accuracy*
1.	16	Normal	1	15	94%
2.	16	Bad	14	2	12.5%
3.	16	Bright	2	14	87.5%
4.	2	Normal	16	0	0%
5.	2	Bright	5	11	69%
6.	2	Bad	16	0	0%

IV. RESULTS

An analysis table for the proposed algorithm is shown in Table I. The table shows that results depend significantly on the camera resolution and illumination conditions. The algorithm was tested using a high and a low resolution camera, under varying lighting conditions. With a 16 Megapixel camera high percentage of accuracy is achieved provided the lighting is normal or bright. Under bad illumination, the results are poor, even with a high resolution camera. When a low resolution camera was used, a high percentage of missed detections were observed. However under bright illumination, results are improved significantly. Table II shows the analysis table for the drowsiness detection techniques discussed in the literature survey. From the table it is clear that the technique proposed by Flares et al is the most efficient, providing an accuracy of 95.6%. This system is able to work under variable lighting conditions and also works if the driver's face is slightly tilted to the side. Their system also provides positive results even if the driver is wearing sun glasses. The second most efficient is Mandeep et al's algorithm which provides 99.4% accurate results with a negligible error rate. The system is non intrusive, that is, it does not distract the driver but the system cannot work under bad illumination conditions. It also does not support driver's wearing sun glasses. Chuang-Wen, et al's technique has shown 83% accuracy over a dataset of 12 videos. The paper does not describe the working of the system under varying face orientations. Flares et al's facial expression recognition is able to cater both varying lighting conditions and different face orientations. It also supports drivers wearing spectacles. However, this paper does not elaborate the test results and percentage accuracy. Sahadhayas et al's technique supports varying lighting conditions and different face positions but this technique does not run quite accurately in real time and is intrusive.

TABLE II. COMPARISON

Ref #	Evaluation Parameters											
	Authors	***Technique***	***Accuracy***	***Testing Data***	***Testability***	***Intrusive***	***Bad Illumination***	***Camera Type***	***Working with sun glasses /spectacles***	***Working with Face Tilted***	***Real time***	***Error Rate***
[2]	Mandeep et al 2012.	Eye Blink Monitoring using Mean Sift Algorithm	99.4%	Not Specified	Yes	No	No	Webcam	Not Specified	No	Yes	1%
[3]	Salvatore, et al 2011.	FPGA based prototyping	Not Specified	Not Specified	Yes	No	Yes	IR CCD Camera	Not Specified	Yes	Yes	Not Specified
[4]	Flares, et al 2009.	Face and Eye monitoring based on neural networks & visual information	95.6%	5	Yes	No	Yes	Monocular Camera	Yes	Yes	Yes	4.4%
[5]	Chuang-Wen, et al 2013.	Computer Vision & Machine Learning Algorithm	83%	12	Yes	No	Not Specified	Dual camera smartphone	Not Specified	Not Specified	Yes	17%
[6]	A.Sahayadhas, et al 2013.	Electroculogram and vehicle based measures	Not Specified	15	Yes	Yes	Yes	Not Specified	Yes	Yes	No	Not Specified
	Proposed Technique	Real Time Drowsiness Detection using Eye Blinks Monitoring	94%	16	Yes	No	No	16MP webcam	No	Yes	Yes	6%

Table II also illustrates comparison of the proposed technique with the previous methodologies. The proposed technique has an estimated accuracy of 94% that is nearly equal to the Flares et al algorithm which had the highest accuracy among the aforementioned techniques. The distinctive quality of this algorithm is that it has been tested on a much larger testing data that is 16 video samples, under varying lighting conditions and camera resolutions. The proposed algorithm is less complex than the Flares et al algorithm and depicts similar accuracy. It is more economical and can be implemented using just a web camera and does not require any other hardware devices for working. Furthermore, it is non intrusive and works well in real time. Drawbacks of this algorithm are that it does not work under poor lighting conditions and requires a clear visibility of eyes. If the eyes are covered with sun glasses, the algorithm would fail in the detection of eyes in the first place and hence will fail in achieving the desired outcomes.

V. CONCLUSION AND FUTURE WORK

We have presented a new eye blink monitoring algorithm to detect drowsiness in real time. This technique gives highly accurate results when used under good illumination conditions and executed using a high resolution camera. This indicates that it has worked well under ideal conditions. We further aim to test the technique on persons with different physical features like wearing eyesight glasses, having facial hair, having some eye disease or having the mouth covered. This would give us more evidence about the versatility of the algorithm. To improve the blink monitoring, the eye point detection must be consistent with each frame. For future work maintaining consistency in the corner detection algorithm will be the priority. Some more effective techniques may be employed to detect the eye feature points more reliably with each video frame. In future, physiological and vehicle measures of the driver can be incorporated with the existing algorithm. Some Artificial Intelligence (AI) capabilities can be added to enhance reliability of the system. The system shall be able to learn the driver's particular blinking patterns, face expressions, driving patterns like acceleration, deceleration rate, steering speed and driver's physiological signs like blood pressure, heart rate and muscle activity when he is about to fall asleep. In this way the system will predict and warn the driver prior to him falling asleep, thus saving him from an accident.

ACKNOWLEDGMENT

We would like to pay our gratitude towards Fatima Jinnah Women University for providing us with a platform and an opportunity to conduct this research.

REFERENCES

[1] World Health Organization (WHO), "Global status report on road safety 2009", Geneva, Switzerland, 2009.

[2] M. Singh, G. Kaur, "Drowsiness detection on eye blink Duration using algorithm", International Journal of Emerging Technology and Advanced Engineering , Volume 2, Issue 4, April 2012.

[3] S. Vitabile, A. D. Paola and F. Sorbello, "A real-time non-intrusive FPGA-based drowsiness detection system", Journal of Ambient Intelligence and Humanized Computing, Volume 2, Issue 4, pp 251-262, December 2011.

[4] M. J. Flores, J. M. Armingol and A. Escalera, "Real-time warning system for driver drowsiness detection Using Visual Information", Journal of Intelligent & Robotic Systems, Volume 59, Issue 2, pp 103-125, August 2010.

[5] C. W. You, N. D. Lane, F. Chen, R. Wang, Z. Chen, T. J. Bao, M. Montes-de-Oca, Y. Cheng, M. Lin, L. Torresani and A. T. Campbell, "CarSafe App: Alerting Drowsy and Distracted Drivers using Dual Cameras on Smart phones", In MobiSys'13, June 25-28, 2013.

[6] Sahayadhas, K. Sundaraj and M. Murugappan," Drowsiness detection during different times of day using multiple feature", Australasian Physical & Engineering Sciences in Medicine, Volume 36, Issue 2, pp 243-250, June 2013.

[7] P. Viola and M. Jones, "Rapid object detection using a boosted cascade of simple features", In Conference on Computer Vision and Pattern Recognition, 2001.

[8] H. Lu, W. Zhang and D. Yang, "Eye detection based on rectangle features and pixel-pattern-based texture features", In Proceedings Of 2007 International Symposium On Intelligent Signal Processing And Communication Systems, Nov 28-Dec 1, 2007 Xiamen, China.

[9] Georgia Regents University, "Eye Image", mcgeyecare.com. [Online].

[10] J. D. Cook, "Three Algorithms for Converting Color to Grayscale", johndcook.com [Online].

[11] Harris and M. J. Stephens, "A combined corner and edge detector", In Alvey Vision Conference, pages 147–152, 1988.

[12] E. Weisstein, "Midpoint" From Math World—A Wolfram Web Resource. [Online]

[13] J. D. Sally and P. Sally. "Chapter 3: Pythagorean triples", Roots to research: a vertical development of mathematical problems, American Mathematical Society Bookstore. p 63, 2007.

[14] McWilliams. "Re: How fast does an eye blink?". University of Missouri- St. Louis. MadSci Network.