

---

---

# Final Project Write Up

## COMP4102A

---

---

Automotive Safety Suite

Authors:

CONNER BRADLEY – 101073585

CHRISTIAN BELAIR – 101078744

ADAM PAYZANT – 101082175

*Carleton University*

February 5, 2020

Abstract

Contents

<b>1</b>	<b>Introduction</b>	<b>2</b>
<b>2</b>	<b>Background</b>	<b>2</b>
2.1	Gaze Detection and Tracking . . . . .	2
2.2	Pedestrian Detection and Tracking . . . . .	2
2.3	Road Sign Tracking . . . . .	2
<b>3</b>	<b>Approach</b>	<b>2</b>
3.1	Gaze Tracking . . . . .	2
3.2	Pedestrian Tracking . . . . .	3
3.3	Road Sign Tracking . . . . .	4
<b>4</b>	<b>Results</b>	<b>4</b>
4.1	Gaze Tracking . . . . .	4
4.2	Pedestrian Tracking . . . . .	4
4.3	Road Sign Tracking . . . . .	5
<b>5</b>	<b>List of Work</b>	<b>5</b>
5.1	Gaze Tracking . . . . .	5
5.2	Pedestrian Tracking . . . . .	5
5.3	Road Sign Tracking . . . . .	5
5.4	GUI Integration . . . . .	5
5.5	Shared Component Integration . . . . .	5
<b>6</b>	<b>GitHub Page</b>	<b>5</b>

# 1 Introduction

The Automotive Safety Suite (ASS) is a collection of safety features which try to solve distracted driving problems using computer vision. The ASS has three main components: Gaze Tracking, Pedestrian Tracking, and Road Sign Tracking. Gaze tracking determines where eyes exist in the driver's camera view and derives gaze in order to determine where it is the driver is looking. Pedestrian Tracking involves trying to identify pedestrians in the application's road view. This component is meant to identify where within the view pedestrians are if they exist. The last component is Road Sign Tracking where using the same road view as Pedestrian Tracking it detects and identifies where within the video frame road signs are if they exist. The main goal is to have a suite of features that work together to avoid distracted driving by notifying the driver whenever their gaze is not within an acceptable range of oncoming road signs or pedestrians.

## 2 Background

### 2.1 Gaze Detection and Tracking

Gaze detection and tracking has many positive implications for driver safety, namely to detect if a driver is distracted or drowsy. The US department of transportation found that in years 2011-2015 an overall 2.5% of fatalities were caused by drowsy driving [4], and for distracted driving in 2018 it was found that 8% of fatalities were distraction-affected [5]. Currently there are a wide variety of well-established and novel techniques for gaze tracking as found by a survey by Chennamma and Xiaohui [2].

### 2.2 Pedestrian Detection and Tracking

Pedestrian detection and tracking is an important aspect in driver safety. Drivers must be aware when one or more pedestrians are moving around their vehicle as to ensure their safety. Stimpson, Wilson, and Muelleman research into pedestrian fatalities shows that from 2005 to 2010 the fatality rate of 116.1 per 10 billion vehicle miles driven had increased to 168.6 in 2010 [7]. OpenCV includes an implementation of the Histograms of Oriented Gradients (HOG) which can identify a person within an image or video. This creates a basis for identifying pedestrians. The implementation details in terms of human detection are found in this paper[3]

### 2.3 Road Sign Tracking

Road signs are vital to road safety. Stop sign violations accounted for approximately 70% of all crashes.[6] In addition, in some areas, speed limits are lowered in unexpected areas pose great risk for a driver, even when they're striving to follow the speed limit. While much research into this area is focused on using machine learning, some computer vision exclusive implementation have been studied.[1]

## 3 Approach

### 3.1 Gaze Tracking

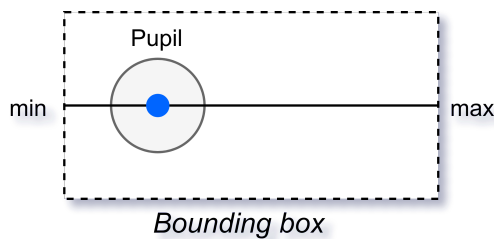
For our gaze tracking component, we investigated a few different approaches to gaze tracking as documented in the survey of gaze tracking performed by Chennamma and Yuan [2]. As depicted in the survey, the most accurate ways to track gaze is with special hardware, which is typically of the form

1. A wearable headset that has two cameras pointed into the eyes, this provides a very accurate gaze that can be approximated by a gaze vector which can then be correlated to a approximate region with a margin of error. This approach is the most effective, and allows the user to move their heads around and still be effective.
2. Multiple infrared cameras that are mounted at two different locations that use the infrared light to illuminate the pupils. This provides an accurate approach as well, and allows for head movement within a certain range.
3. A single camera can be used to detect pupils (eye tracking); however they can't reliably detect a vector where the eyes are looking. A single camera also does not allow a user to move their head.

Since we are using limited equipment for the ASS suite, we decided to use option (3) and tweak an existing library to derive a form of gaze. We used an reference implementation of Fabian Timm's algorithm [8] which is capable of deriving bounding boxes.

Our eye tracking pipeline functions as follows:

1. Using OpenCV's cascade classifier, we attempt to detect the available faces in the image. For this we are using a pre-trained cascade file that is designed for frontal facing images.
2. If no face is detected, do nothing. Otherwise, we can attempt to find the eyes.
3. Divide the found face into two regions, each region will contain one eye as the face is a fairly centered bounding box. We can derive a relative eye region by partitioning the face with some constant values.
4. Using the eyeLike library [9] (reference implementation of Timm's algorithm), find the center of the eye (pupil).
5. Derive and draw rectangle based on the previously found bounding boxes, place the pupil inside the rectangle.
6. At this we know where the pupil is relative to a bounding box; however, we have not estimated gaze. Thus, we normalize all the values of the eye region and eye center to be relative to the bounding boxes
7. We then consider a one-dimensional plane (a line in the x-axis) which starts at the minimum edge of our bounding box, ends at the maximum edge of the bounding box, and then uses the pupil position as the point on the line. See diagram below



Between the min and max values is the pupils location, this can be used to derive a percentage as follows (assuming the coordinates have been normalized to min):

$$\frac{pupil.x}{max.x}$$

This percentage is the percentage to the left or right, where 50% is dead center.

8. We average the percentages between left and right eyes to derive an overall percentage.
9. After some testing, we determined if the eye location is less than 40% the eye is pointed right, if the eye is more than 60% the eye is left, else the eye is centered.
10. We render the findings to the mat, update our application's centralized eyeState value, and return.

### 3.2 Pedestrian Tracking

Pedestrian tracking is achieved through a single function which takes in a *cv::Mat* object that represents the current frame of the video and returns a custom data structure called *PedTrackingResult*. The function initializes an instance of OpenCV's *HOGDescriptor* object. With the help of OpenCV, this object can be passed a human detection method which can be passed to the *HOGDescriptor*. Once this method is passed to the *HOGDescriptor*, a clone of the original frame is produced. From here, the process of identifying humans in the frame is done by the work of the *HOGDescriptor* using its *detectMultiScale()* function after converting the input frame from four channels to one channel as needed by the function. This function produces a vector of *cv::Rect* objects representing the bounding boxes for human-shaped objects in the frame and the weights associated with these bounding boxes. From here each *cv::Rect* object in the frame is drawn onto the frame with its associated weight. The resulting frame and *cv::Rect* vector is returned to the image pipeline in order to display the frame and to calculate driver attentiveness.

With the returned vector we first calculate the centre of the width for each *cv::Rect* object. We then compare this center pixel against which third of the main video width the bounding box's centre lies in. We then compare the current eye state to this pedestrian object state and see if the driver is looking at the same third. This process is applied to each bounding box until the end of the list has been reached. Since there are three thirds of the window, if there are an even number of objects detected in each window then we can say that the minimum rate for attentiveness is a third of the total detected pedestrians. This means that if a driver pays attention to third with the most number of pedestrians then the minimum threshold needed for the classification to be passable for driving is  $\frac{1}{3}$ .

### 3.3 Road Sign Tracking

## 4 Results

### 4.1 Gaze Tracking

Our testing results were done with both a laptop web camera, and a higher quality standalone camera. We recommend lower-resolution cameras as it puts less strain on the pipeline's algorithm. Our gaze tracking works under the assumption that the face is parallel to the camera, thus any large head turns will cause erratic results as the pipeline relies on the symmetry of the face to derive bounding boxes for the eyes (the bounding boxes are shown below in white).



Figure 1: Gaze tracking, straight. In the top lefthand corner of the window is the current eye tracking state



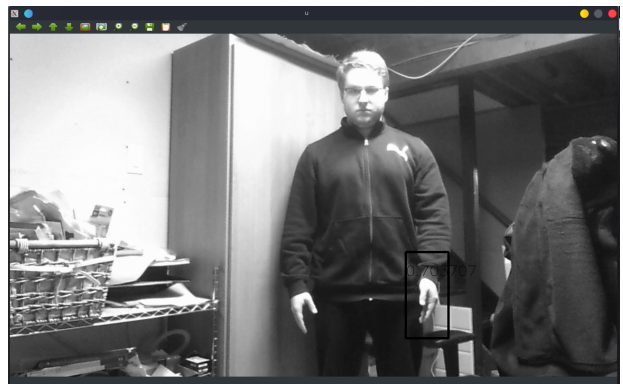
Figure 2: Gaze tracking, right. In this example the left bounding box mistook the dark region of hair as a pupil

### 4.2 Pedestrian Tracking

The original testing results when testing with a laptop camera were a little lackluster. For the most part, the use of the HOG descriptor using this webcam resulted in inaccurate readings of human objects within the frame. Mostly it would detect human-like objects in the negative space between objects. An example of this would be when someone was standing reasonably far away from the camera and the HOG descriptor would identify human-shaped objects in the armpits of the subject standing in front of the camera or in the surrounding spaces. Another example is when the subject was standing in front of the camera with their hand turned sideways. This issue arose because the quality of the camera used produced a significant amount of noise in each frame resulting in changes in gradients.



(a) Detected Armpit Error



(b) Detected Hand Error

Figure 3: Errors produced using a noisy webcam

Later, testing started to use video files to be more in line with how we wanted to achieve this

project. The video used was of a motorcyclist who had a camera attached to their helmet and was riding around while driving by careless pedestrians. When viewing the results of the video file, the accuracy of the HOG descriptor was much more in line with what we had hoped. Most if not all of the pedestrians were identified when within an acceptable range. Whenever the pedestrian tracking component produced a false negative, the cases that generated such errors were those where either a pedestrian was too far from or too close to the camera, and whenever the pedestrian was partially occluded. Both of these conditions are not out of the ordinary since being too close to the camera results in some occlusion since the pedestrian will be partially in frame. When too far away, the gradients in the HOG descriptor become harder to determine if they are human-shaped objects which is normal in nature. Partial occlusion of a pedestrian in the frame is also normal as parts of the gradient data is lost due to occlusion.

### **4.3 Road Sign Tracking**

## **5 List of Work**

### **5.1 Gaze Tracking**

- Conner Bradley

### **5.2 Pedestrian Tracking**

- Christian Belair

### **5.3 Road Sign Tracking**

- Adam Payzant

### **5.4 GUI Integration**

- Conner Bradley
- Christian Belair
- Adam Payzant

### **5.5 Shared Component Integration**

- Conner Bradley
- Christian Belair
- Adam Payzant

## **6 GitHub Page**

<https://github.com/ChristianBelair/COMP4102-Project>

## References

- [1] Tarik "Ayaou, Mourad Boussaid, Karim Afdel, and Abdellah Amghar". Improving road signs detection performance by combining the features of hough transform and texture. *arXiv preprint arXiv:2010.06453*, 2020.
- [2] HR Chennamma and Xiaohui Yuan. A survey on eye-gaze tracking techniques. *arXiv preprint arXiv:1312.6410*, 2013.
- [3] N. Dalal and B. Triggs. Histograms of oriented gradients for human detection. 1:886–893 vol. 1, 2005.
- [4] US Department of Transportation. Crash stats: Drowsy driving. *Traffic Safety Facts*, DOT HS 812 446, 2015.
- [5] US Department of Transportation. Research note: Distracted driving. *Traffic Safety Facts*, DOT HS 812 926, 2018.
- [6] Richard A. Retting, Helen B. Weinstein, and Mark G. Solomon. Analysis of motor-vehicle crashes at stop signs in four us cities. *Journal of Safety Research*, 34(5), 2003.
- [7] Jim P. Stimpson, Fernando A. Wilson, and Robert L. Muelleman. Fatalities of pedestrians, bicycle riders, and motorists due to distracted driving motor vehicle crashes in the u.s., 2005–2010. *Public Health Reports*, 128(6):436–442, 2013. PMID: 24179255.
- [8] Fabian Timm and Erhardt Barth. Accurate eye centre localisation by means of gradients. pages 125–130, 01 2011.
- [9] Trishume. trishume/eyelike.