Contract Book

Monitoring and Alerting System for Driver Fatigue and Distraction

Version 1.1

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EN.520.427.01.FA17 Product Design Lab

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Abstract

Driver fatigue is a major leading factor in accidents at the wheel. We propose a preventative system of detecting driver fatigue that warns vehicle drivers against imminent danger situations. This compact system operates as a windshield-mounted device with an infrared rear-facing camera that not only tracks a user's facial features, but also analyzes pupil behavior to detect fatigue or distraction in drivers. The camera module streams in real-time and utilizes image processing for feature extraction. This product can be incorporated in both passenger and commercial grade vehicles. Whereas other products on the market focus solely on either fatigue or distraction, this invention combines both capabilities within a compact module and allows user configuration of multiple sensitivity settings.

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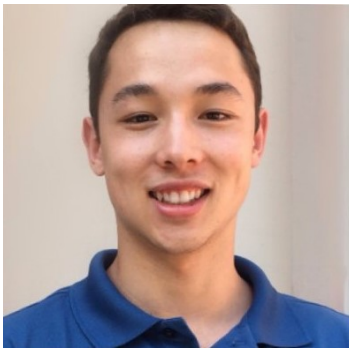
Introduction

This product aims to prevent vehicular accidents resulting from driver fatigue or driver distraction. By maintaining camera feeds of not only the driver's fatigued status, but also of distraction levels, we propose the design of a new product that has increased capabilities as compared to similar devices already present in the market. This device would create a high impact to transportation safety, as demonstrated by the multitude of surveys conducted by vehicle safety administrations.

The NHTSA estimates that perhaps as many as 100,000 accidents annually can be traced to drivers who actually doze off behind the wheel of their vehicles. Nearly half of semi-truck drivers in one study admitted to "drifting off" while driving a long-haul route.[1] Additionally, according to a 2015 survey done by the Federal Motor Carrier Safety Administration, fatigue was the #1 leading factor for distracted/impaired drivers of large trucks. With an average cost of $330,000 for an injury due to a vehicular accident, an unexpected spike in these incidents can put a fleet in serious jeopardy.[2] Vehicle crashes result in significant property damage, and miles traveled by vehicles are only increasing by the year. For instance, from 2013-2014, miles traveled by vehicles increased by 1.5% for large trucks and by 5.5% for buses. There was a 31% increase in crashes that resulted in property-only damage.[3]

Founders



Michael Ashmead is a Computer Science and Electrical Engineering undergraduate at Johns Hopkins University. He is minoring in Business Management and Entrepreneurship with a focus in Leadership & Organizational Behavior.

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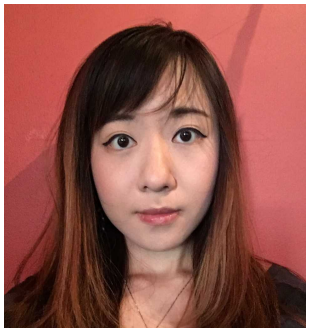
[1] Baumgartner Law Firm. "Drowsy Drivin g- Common Cause of Semi-Truck Accidents." HG.org. HGExperts.com, n.d. Web. 21 Sep. 2017. <https://w ww.hg.org/article.asp?id=29866>.

[2] "Data + Analytics." Omnitracs. Omnitracs, n.d. Web. 21 Sept. 2017. <http://w w w.omnitracs.com/solutions/data-analytics>.

[3] "Large Truck and Bus Crash Facts 2015." Federal Motor Carrier Safety Association <https://www.fmcsa.dot.gov>.

Michael is currently a Full Stack Developer at ForagerOne, a startup funded by Johns Hopkins University that is helping undergraduates find research.

He is passionate about using technology to solve problems.



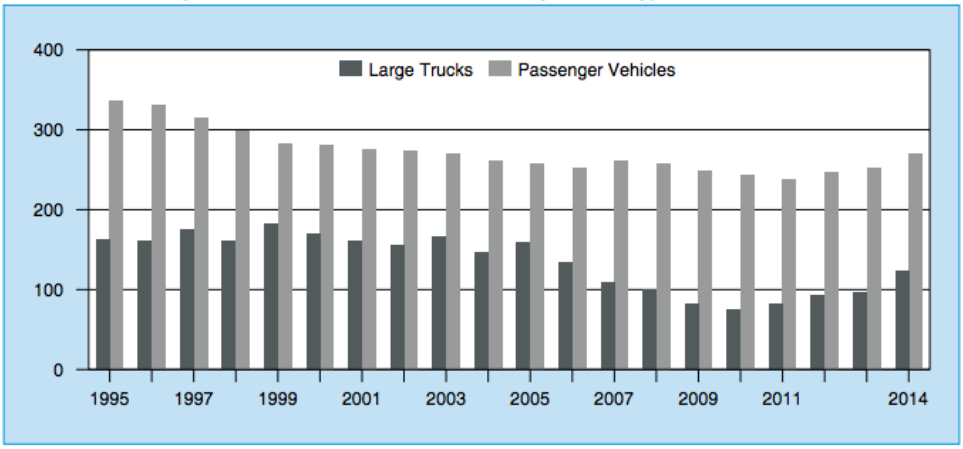
Lousanna Cai is a Computer Engineering undergraduate at Johns Hopkins University. She has a concentration in software architecture with interests in hardware systems. She works in research groups studying 3-D image processing and visualization.

She is passionate about problems of scalability and performance tuning.

Field Survey

The Federal Highway Administration provides survey statistics on the automobile accidents resulting in either fatalities or property damage. The survey provides data on both large trucks and passenger vehicles.

Trends Figure 6. Large Trucks and Passenger Vehicles Involved in Property Damage Only (PDO) Crashes per 100 Million Vehicle Miles Traveled by Vehicle Type, 1995-2014*

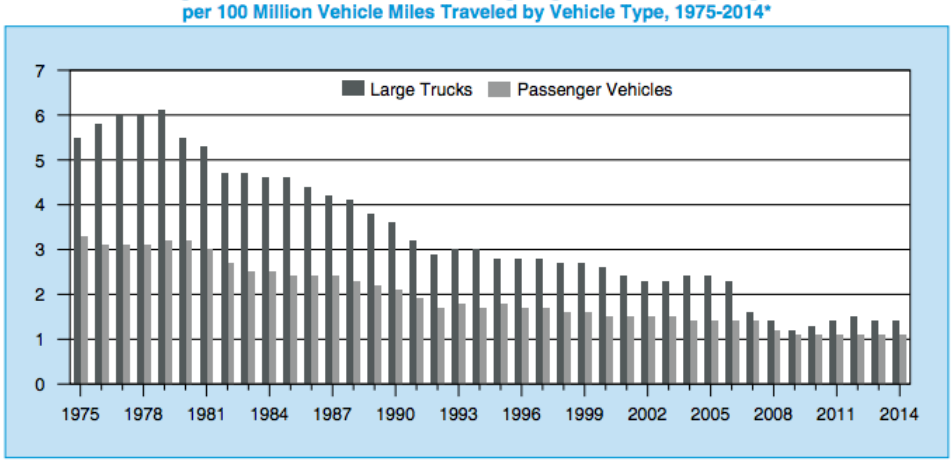


*At the time of publishing, the Federal Highway Administration (FHWA) has not released the 2015 data files for vehicle miles traveled (VMT) or for registered vehicles. This publication will be updated when they are available.

Notes: A large truck is defined as a truck with a gross vehicle weight rating (GVWR) greater than 10,000 pounds. A passenger vehicle is defined as a car or light truck (including pickups, vans, and sport utility vehicles). FHWA implemented an enhanced methodology for estimating registered vehicles and vehicle miles traveled by vehicle type beginning with data from 2007. As a result, involvement rates may differ, and in some cases significantly, from earlier years.

Sources: Vehicle Miles Traveled and Registered Vehicles: FHWA, *Highway Statistics 2014*. PDO Crashes and Vehicles Involved: National Highway Traffic Safety Administration, General Estimates System (GES).

Trends Figure 3. Fatalities in Crashes Involving Large Trucks and Passenger Vehicles per 100 Million Vehicle Miles Traveled by Vehicle Type, 1975-2014*



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Sources: Vehicle Miles Traveled: FHWA, *Highway Statistics 2014*. Fatalities and Vehicles Involved: National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS).

Intended Use

This product is intended to be mounted to the center of the dashboard for either a consumer or commercial grade vehicle. It is to be charged via USB to the automobile's DC connector. The user-facing camera should be directed along a ray pointing to the front of the user's face, and it should be positioned within two feet of the user's face. The user interface screen is touch-sensitive, and tactile input is required to configure device settings prior to road usage.

After installation and pre-configuration, the device should not be moved from its original position. If it is tampered with during use, re-calibration is necessary for maximum function. The user can choose his or her desired visual and/or auditory alerts, and he or she can choose a desired sensitivity setting (i.e. low, standard, high).

Patent Survey

1. System for Monitoring Eyes for Detecting Sleep Behavior (5,570,698) (Expired)
    a. Transforms an image sequence into a one dimensional signal by extracting relevant features from the images
    b. Transformation of the image sequence includes eye localization, eye tracking, and eye motion signal generation
    c. The system takes advantage of the relatively high horizontal-contrast density of the eye region to determine eye positions in a greyscale image of a human face
    d. Analysis of the signal generated then occurs to detect sleepiness
2. Apparatus and method for responding to the health and fitness of a driver of a vehicle (6,734,799) (Active)
    a. The apparatus includes means for non-intrusively sensing at least one health condition of the vehicle occupant and for producing a first output signal indicative of the health condition of the vehicle occupant
    b. The apparatus further includes a means for transmitting a health condition signal derived from the first output signal to a person at a location remote from the vehicle
    c. Our device will not be tracking such a wide array of inputs
3. Algorithm for monitoring head/eye motion with one camera (6,927,694) (Active)
    a. Tracks a person's head and facial features with a single on-board camera
    b. Can initialize automatically, and can reinitialize when it needs to
    c. System can classify rotation in all viewing directions, detect eye/mouth opening/closing, detects eye blinking, and recovers the 3D gaze of the eyes
    d. Our algorithm will differ from this
4. Cost effective and robust system and method for eye tracking and driver drowsiness identification (9,483,695) (Active)
    a. Real-time tracking of the face and localizing eye bounding box within the face bounding box in the captured image by comparing the gray values with threshold using the segmentation process
    b. The target model histogram and target candidate model histogram are computed based on the feature space
    c. Detecting the drowsiness state of the eyes using histogram equalization
    d. Our algorithm differs from this
5. Driver distraction and drowsiness warning and sleepiness reduction for accident avoidance (9,460,601) (Active)
    a. Telematics device for driver monitoring (is connected to the internet)

b. Determines speed of vehicle
c. Calculating a maximum allowed drowsiness time in accordance with speed of said vehicle and allowed drowsiness travel distance
d. Our device and algorithm differ

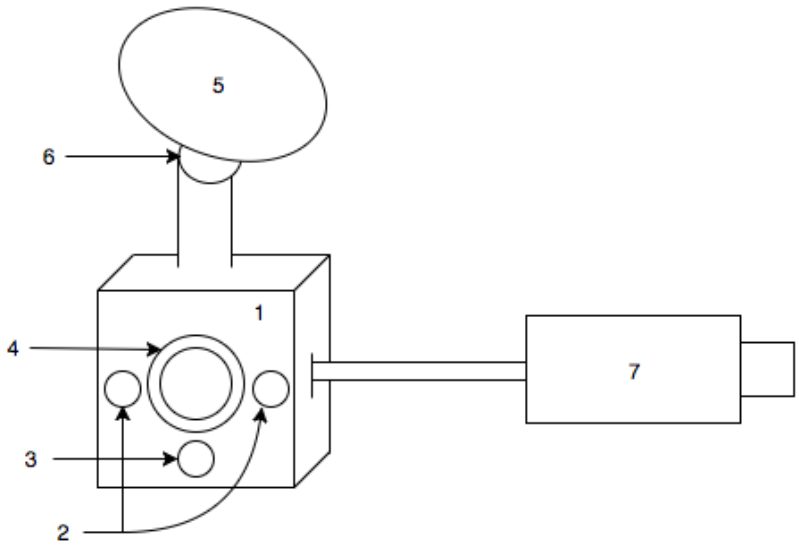
Regulatory Issues

OpticalTrack does not guarantee 100% accuracy of fatigue or distraction detection, and users would be reminded of this prior to utilization. There may be insurance savings implications for companies that choose to use our device.

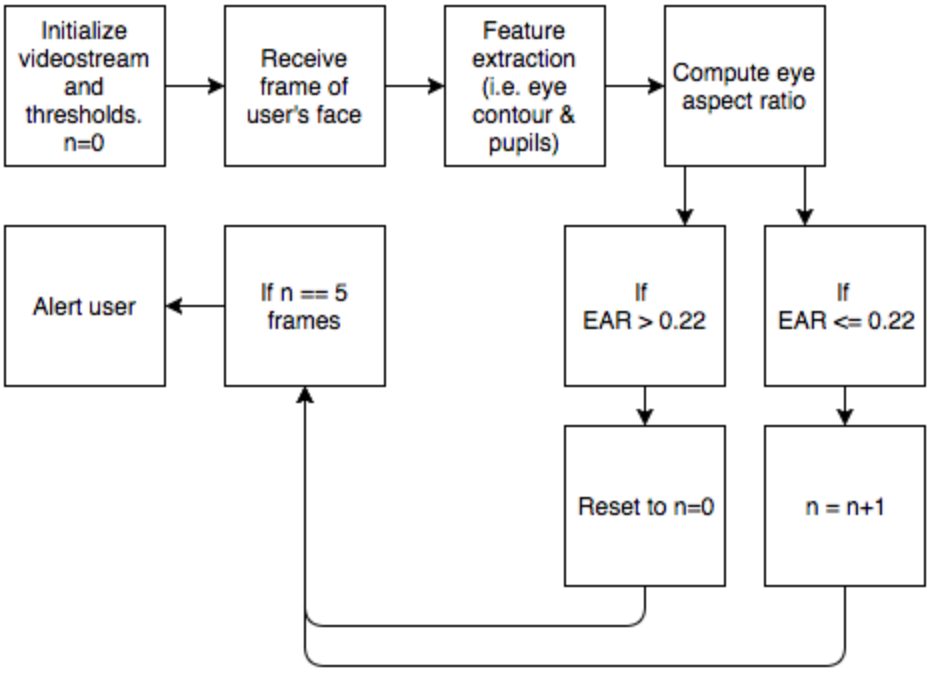
Driver behavior is completely private, and OpticalTrack does not track user data. If this were to change in the future, data would remain anonymous, and users would be prompted in advance for their permission to collect anonymous statistics. This would serve the sole purpose of improving product performance.

Schematic

Figure 1

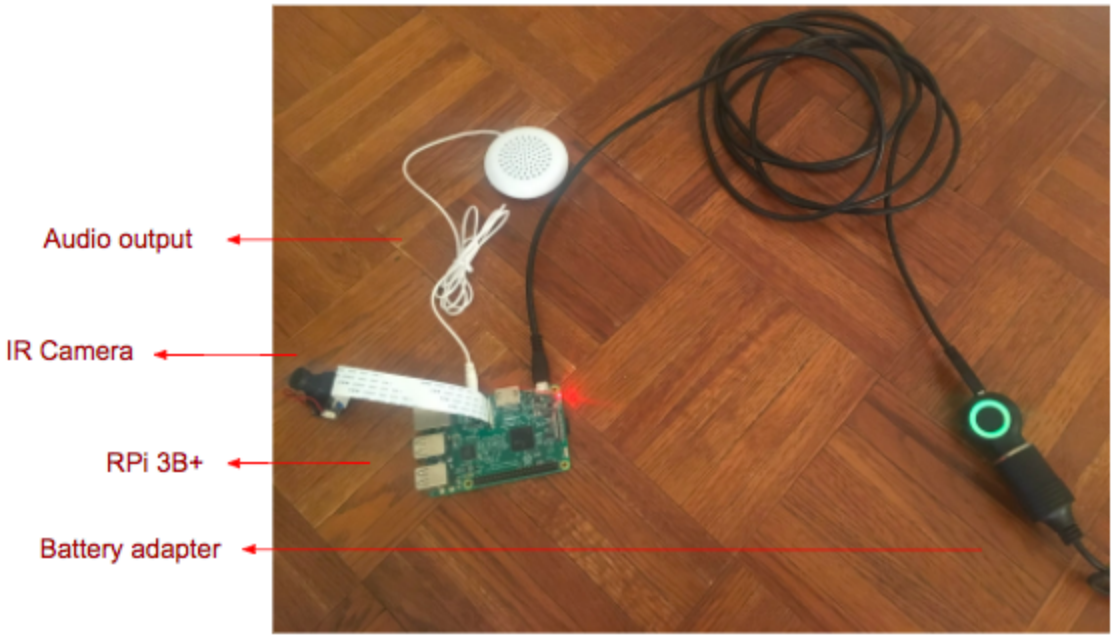


1. Plastic Case
2. Infrared Light Sources
3. Speaker
4. Infrared Camera
5. Suction Cup
6. Ballpoint Junction
7. Car Adapter



Detailed Design

Hardware



Software

Dependencies: Python, OpenCV, dlib, imutils

1. Initialize video stream via enabled camera module.
2. Initialize thresholds.
    a. Frame Threshold = 3
    b. Eye Aspect Ratio (EAR) Threshold = 0.22
        i. Open eyes ratio remains around 0.3
        ii. Fatigued eye ratio remains around 0.2
        iii. Distracted eye ratio fluctuates around 0.2-0.22 due to increase of blink frequency and decrease of blink velocity
3. Compute EAR for each frame received through stream.
    a. Increment global frame-count each time EAR falls below threshold.
    b. If EAR is above threshold, then reset global frame-count to zero.
    c. If global frame-count reaches frame-threshold, play MP3 alert.

Communication

Communication on the engineering team will be managed through Slack, Google Drive, and Google Hangouts when necessary. Slack is excellent for managing simple messaging, Google Drive is great for file management, and Google Hangouts is great for group video calling.

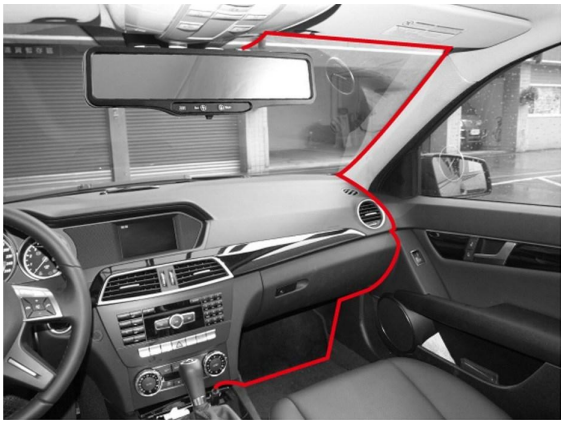
Google Drive is particularly important because it will allow us to record all research that we are doing.

We will be communicating with our patent lawyer and investors via email and at their office or ours. We want to find a lawyer and investors that will be locally based so that it is easy to communicate and so that they can see our product first-hand.

Instruction Manual

<u>Use</u>
Our device does not have any buttons on it. It simply turns on when the driver turns on the vehicle.

<u>Installation</u>
We will provide installation services to trucking companies. Our installation is very simple and doesn't require any special tools. We will wire the device as depicted below (installation is identical to a truck's):



Reimbursement

Since this is not a medical device, there will not be reimbursement from insurance providers, however, there could be a discount rate or something similar for company insurance plans.

Business Model

Our business model is simple. We want to develop a superior product to what is on the current market for a cheaper price point. We believe we can sell our device for approximately $50 and manufacture it for $25 at scale. Based on materials and complexity, our device is very similar to an Amazon Alexa for example, so we believe $25 is very possible.

Financial Plan

Cash Needed for Two Years: $300,000

20 Prototypes for 1 Fleet	$1,000
1 Additional Researcher	$200,000
Patent Filing Costs	$15,000
LLC Filing Costs	$888
Materials & Tools	$30,000
Office Space	$48,000

Website

Our website would ideally be hosted on www.opticaltrack.com. Although the domain has an owner, there is currently no website hosted at the domain. The Whois database states that the domain is currently privately registered through 1&1 Internet SE. If we can neither find the owner nor purchase the domain, we will purchase www.getopticaltrack.com.

Logo and Trademark

There are currently no trademarks, live or dead, for OpticalTrack. After doing a Google search, we were unable to find any products or companies named OpticalTrack either. In order to make sure there aren't any trademarks for similarly named companies we also searched for OpticalTracks and OpticalTrak. There currently aren't any live or dead trademarks registered for these names either. However, there is a live registered trademark for OptiTrack, though this is far enough from our name that it shouldn't matter.

Patent

Provisional Application for United States Patent

TITLE: Monitoring and Alerting System for Driver Fatigue and Distraction
INVENTOR(S): Michael Ashmead, Lousanna Cai

BACKGROUND
Driver fatigue is a major leading factor of accidents at the wheel. A study conducted by the Harvard School of Medicine found that 50% of the surveyed truck-drivers admitted to drifting off

at least once during a long-haul route. The United States Department of Transportation estimates that over 500,000 truck accidents occur each year. The National Highway Traffic Safety Administration estimates that as many as 100,000 accidents annually can be traced to drivers who doze off behind the wheel.

This invention aims to prevent vehicular accidents resulting from driver fatigue or driver distraction. By maintaining camera feeds of not only the driver's fatigued status, but also of distraction levels, we propose the design of a new product that has increased capabilities as compared to similar devices already present in the market. Whereas other products on the market focus solely on either fatigue or distraction, this invention combines both capabilities within a compact module and allows user configuration of multiple sensitivity settings. This device would create a high impact to transportation safety, as demonstrated by the multitude of surveys conducted by vehicle safety administrations.

BRIEF SUMMARY OF THE INVENTION

The invention structurally consists of a printed circuit board with the system on chip. An infrared camera module has been mounted to the 15-pin MIPI camera interface connector on board. An audio output device is connected to the 3.5mm audio jack, and a 5V battery adapter powers the board.

The infrared camera module streams live footage of the user's facial features, whereby pre-installed software on the system executes the algorithm for eye and pupil analysis. Upon falling below the preconfigured thresholds, the audio device relays a continuous alert to the user.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1. Figure 1 shows the hardware schematic that is to be mounted to the user's dashboard. The labeled components are listed below.

1. Plastic Case
2. Infrared Light Sources
3. Speaker
4. Infrared Camera
5. Suction Cup
6. Ballpoint Junction
7. Car Adapter

Figure 2. Figure 2 illustrates the algorithmic flowchart.

Figure 1

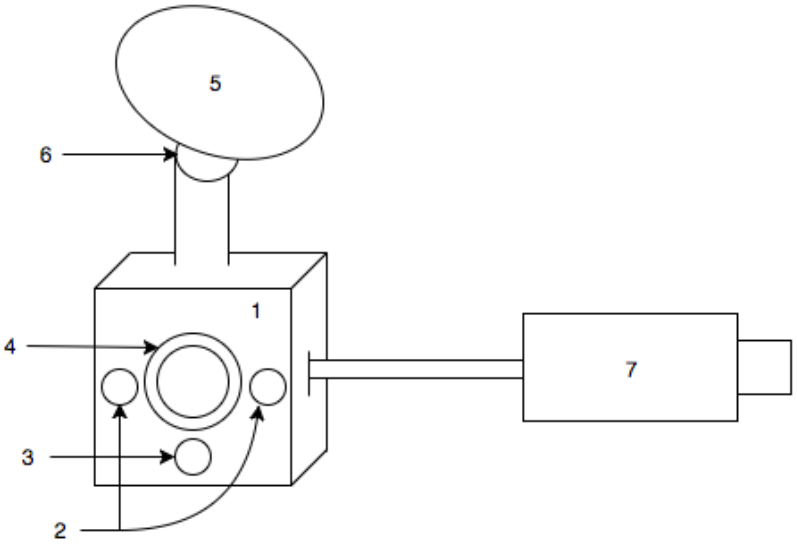
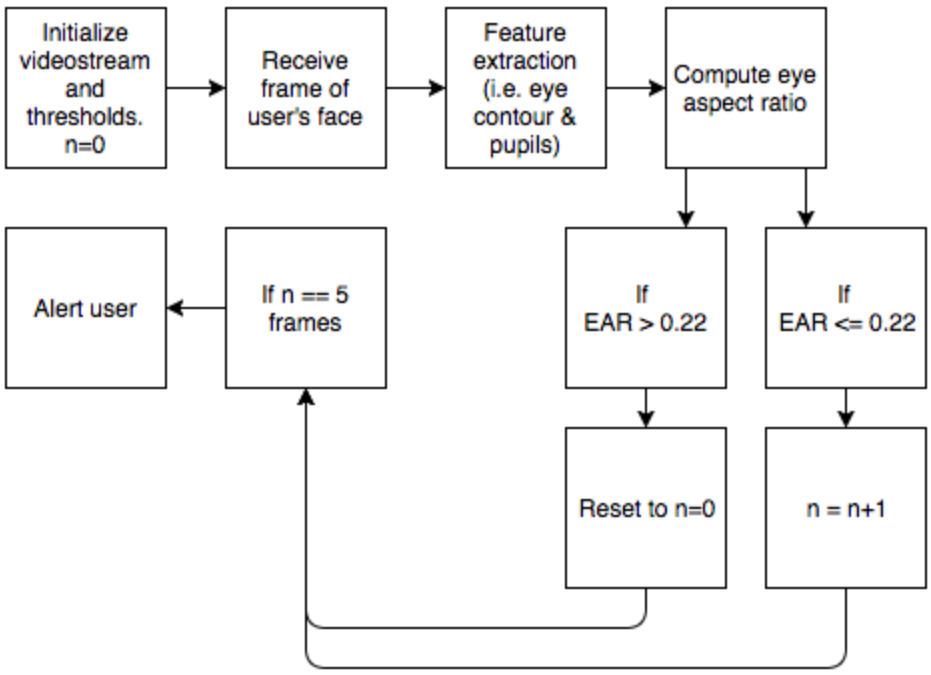


Figure 2



DETAILED DESCRIPTION AND BEST MODE OF IMPLEMENTATION

This product is intended to be mounted to the center of the dashboard for either a consumer or commercial grade vehicle. It is to be charged via USB to the automobile's DC connector. The user-facing camera should be directed along a ray pointing to the front of the user's face, and it

should be positioned within two feet of the user's face. The user interface screen is touch-sensitive, and tactile input is required to configure device settings prior to road usage. After installation and pre-configuration, the device should not be moved from its original position. If it is tampered with during use, re-calibration is necessary for maximum function. The user can choose his or her desired visual and/or auditory alerts, and he or she can choose a desired sensitivity setting (i.e. low, standard, high).

Upon first execution, the video stream is initialized via the pre-enabled camera module. Both the frame threshold and eye aspect ratio threshold are initialized to 3.0 and 0.22, respectively. As blink frequency increases and blink velocity decreases, the eye aspect ratio has been found to fluctuate between 0.20 and 0.22 from field observation. For each frame that is received through the camera module for analysis, the eye aspect ratio is computed to see if it falls below the threshold. If the eye aspect ratio is above the 0.22 threshold, the global frame-count is reset to nil. If the global frame-count meets the frame threshold, then an MP3 alert is played continuously from the audio speaker until the user's computed eye aspect ratio once again rises above the threshold.

ABSTRACT:
We propose a preventative system of detecting driver fatigue that warns vehicle drivers against imminent danger situations. This compact system operates as a windshield-mounted device with an infrared rear-facing camera that not only tracks a user's facial features, but also analyzes pupil behavior to detect fatigue or distraction in drivers. The camera module streams in real-time and utilizes image processing for feature extraction. This product can be incorporated in both passenger and commercial grade vehicles. Whereas other products on the market focus solely on either fatigue or distraction, this invention combines both capabilities within a compact module and allows user configuration of multiple sensitivity settings.

Elevator Pitch

Driver fatigue is a major leading factor of accidents at the wheel. A study conducted by the Harvard School of Medicine found that 50% of the surveyed truck-drivers admitted to drifting off at least once during a long-haul route. The United States Department of Transportation estimates that over 500,000 truck accidents occur each year. The National Highway Traffic Safety Administration estimates that as many as 100,000 accidents annually can be traced to drivers who doze off behind the wheel.

We propose a preventative system of detecting driver impairment to alert vehicle drivers against imminent danger situations. This compact system operates as a windshield-mounted device with an infrared camera that not only tracks a user's facial features, but also analyzes pupil behavior to detect fatigue or distraction in drivers. This product can be incorporated in both passenger and commercial grade vehicles. Whereas other products on the market focus solely

on either fatigue or distraction, this invention combines both capabilities within a compact module and allows user configuration of multiple sensitivity settings. This invention thus exceeds the capability of similar products on the market.

Investor Slideshow

OpticalTrack prevents accidents by alerting a driver of fatigue or distraction.

Michael Ashmead and Lousanna Cai

JOHNS HOPKINS UNIVERSITY

Background Problem and Potential

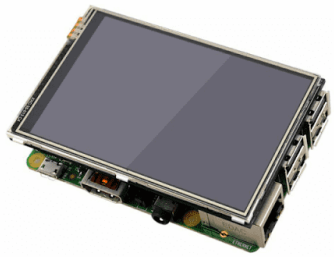
- Trucking
  - 100,000 accidents caused annually by fatigued drivers (trucks and non-trucks) (NHTSA)
  - 84% of distracted-driving-related fatalities in the US were tied to the general classification of carelessness or inattentiveness (NHTSA)
  - Average cost of $200,000-$350,000 per trucking accident
  - Driver eye-tracking technology industry valued at $456.6 million currently
- Airline pilots
  - 56% admitted sleeping while in charge of a plane, 29% stated that they have woken up to find the other pilot asleep as well.
- Train operators

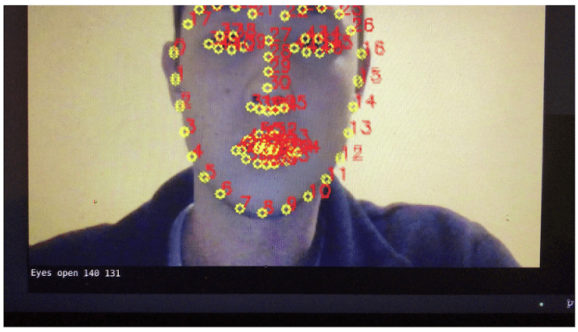
Product Proposal

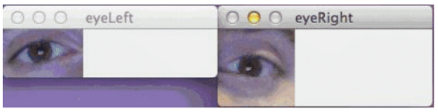
- We are developing a windshield-mounted infrared camera that alerts an operator if they are fatigued, falling asleep, or cognitively distracted using advanced computer vision techniques.
- The device can track key visual features without visible light and through glasses and most sunglasses.

Technology

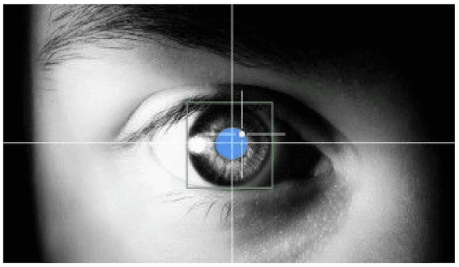
- Compact infrared camera module with tactile interface
  - Expected total cost of approx. $50
- Feature extraction
  - Eye Aspect Ratio
  - Blink Rate and Blink Velocity
  - Pupil Tracking
    - Visual distraction
    - Cognitive distraction







Industry Analysis



- Global driver safety industry
  - Eye-Tracking Technology to emerge as most lucrative segment
    - Valued at $456.6 million currently and will represent a share of 23.8% of the market by 2017 end
    - Rising at an impressive CAGR of 8.1% from 2017 to 2022, the eye-tracking technology segment is projected to reach $673.7 million by the end of the forecast period, representing a share of 24.5% of the overall technology market
    - Annual growth is pegged at $43.4 million annually during 2017–2022.

Competitors

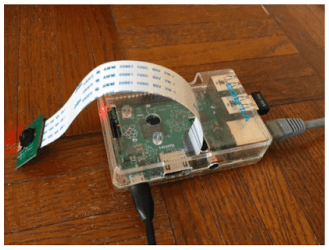
Product Name	Company	Description
Eagle Portable	Optalert	Portable touch screen & wireless glasses.
Driver Fatigue Warning System	Care Drive	Camera on dashboard detects when gaze moves to side window.
Driver Fatigue Detection System	StopSleep	Wearable ring measuring skin conductivity. Vibrates and makes auditory alarm.
Sleep Watcher XR	Exeros	Detects sleepiness in eyelids and retina via IR camera.
Vuemate	Rear View Safety	Camera on dashboard using IR detection. Visual + auditory alarm.

Competitive Advantage

- Cheaper and Easier Installation
  - No need to wear at all times
  - Easy mount and plug into standard cigarette-lighter sockets
  - Current market devices start at $199.99
  - Sensitivity configuration
- Earlier Detection
  - Provides a scale on how tired the driver is before the driver begins falling asleep.
- Detects Cognitive Distraction
  - "Zoning-out" detection

Investment and Future Plans

- Complete and test initial prototypes with customers
- Initially target local companies
  - Baltimore, Maryland
    - 100,000 truckers in Maryland alone
    - Each trucking company employing ~20-30 truckers
- Asking for $300,000
  - Research, 20 Prototypes, Patent costs, LLC Corporation



Summary

Our device is superior to the current devices out there. Clearly, there is a demand for these products, as there is already significant competition in this area. Our device, with the help of the most advanced research, will allow us to out-innovate others. We want to truly revolutionize driving safety and hope that someday our technology will be used, not only in trucks, but also in many other vehicles operated by humans. Even with the rise of automation, we have significant runway before full automation has arrived, and even then, we are considering how our technology can be integrated.