# Horizontal Gaze Nystagmus Detection in Automotive Vehicles

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## ABSTRACT

We propose the development of a device aiming at detecting alcohol intoxication. Because most blood alcohol calculators are fairly invasive and/or expensive, we rely on the detection of nystagmus in intoxicated users. Nystagmus is the involuntary eye movements caused by the ingestion of drugs or alcohol. The test is currently manually implemented by police forces upon arrest, to determine whether a driver is drunk or not. Ideally, we would like to integrate this device to a vehicle to prevent users from taking the wheel drunk.

## 1. INTRODUCTION

Drunk driving took the lives of over 10,000 persons in the US in 2010 alone [1]. This accounts for nearly a third of all traffic-related deaths. Law enforcement has only been minimally successful in catching drunk drivers before fatalities occur, using Blood Alcohol Content (BAC) to measure the level of intoxication of an individual. There exist a few technologies that attempt at addressing this issue.

Breathalysers, the most widely used technology, remain prone to detection errors: alcohol tolerance varies according to various factors, particularly the Body-Mass Index (BMI), and thus is subject to wide variations from person to person. This is the reason why Preliminary Breath Testers (PBT) readings using hand-held devices are not considered an admissible measure of impairment in U.S. courts [2]. Moreover, their portability is mitigated by the necessity for regular calibration. An average wait time of 20 minutes is also required between readings.
Blood sample analysers using scattering provide the most accurate results. While they are admissible in court, they are expensive, sometimes invasive, and most importantly, not portable [3].

Currently, US law enforcement conduct Field Sobriety Tests (FST), a set of physical tests including Nystagmus detection (also called Horizontal Gaze Nystagmus, or HGN). FSTs are admissible in court, as a primary measure of impairment. NHTSA studies [4] report that an accuracy of 77% is observed on the field, principally due to improper training to successfully conduct the test.

We aim at taking advantage of the ubiquity of smartphones to implement Nystagmus detection using computer vision algorithms, bluetooth communication capabilities and a strip of addressable LEDs. The device can then be used by law enforcement authorities to either detect DUIs with minimal interaction with the driver, or as a precautionary use to prevent drunk users from taking the wheel.

This device can find relevance as a consumer product. Individuals may ensure they are not about to drive while legally intoxicated. Furthermore, car manufacturers can integrate this device in their vehicles as a locking mechanism to prevent users from driving drunk.

## 2. RELATED WORK

A number of applications currently populate mobile platforms, aiming at determining whether a user is intoxicated or not. The diverse of detection strategies span a wide range of interaction level: from plain informative facts, to BMI-based calculators (*R-U-BUZZED? BAC Calculator*), to dexterity games (*Blood Alcohol Calculator*, *DUI Dodger*).

While achieving various degrees of detection success, the nature of the interaction requires that the inebriated user engage in a game environment. We aim at minimizing that intellectual involvement by providing simple cues to follow with minimal mental effort.
Although automating Horizontal Gaze Nystagmus has been attempted with *Breathaleyes*, the application does not feature a ground truth cue signal, which provides further detection capabilities.
With regards to eye tracking, there exists a multitude of research on the subject [5][6][7], notably in the field of computer vision and human-computer interaction. Tracking has been achieved at subpixel accuracy.

## 3. SYSTEM OVERVIEW

The proposed system is comprised of 2 blocks: the user constitute one block, while the device represents the other.

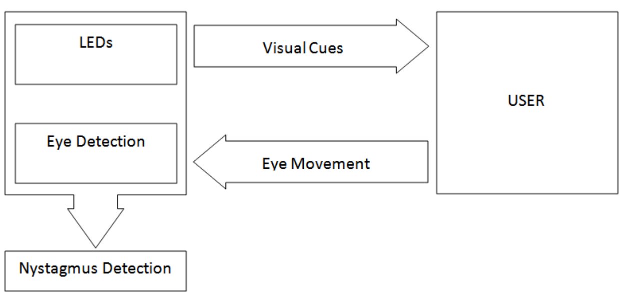


Figure 1: System Overview

The interaction of the two blocks, and the discrepancies between the visual cues and the recorded eye movements, as described in Figure 1, are processed in the detection block.
The system then classifies the user under test as intoxicated or sober. That information can then be utilized for preventive purposes, or as an indicator of intoxication.

## 4. SYSTEM DETAILS

The hardware component of the system is composed of a strip of 20 addressable LEDs, spanning 45cm. A microcontroller with added Bluetooth capabilities displays a sinusoidal sweep across the LED strip, at a fixed frequency $f_0$. The WS2801 driver is used to address the LEDs.

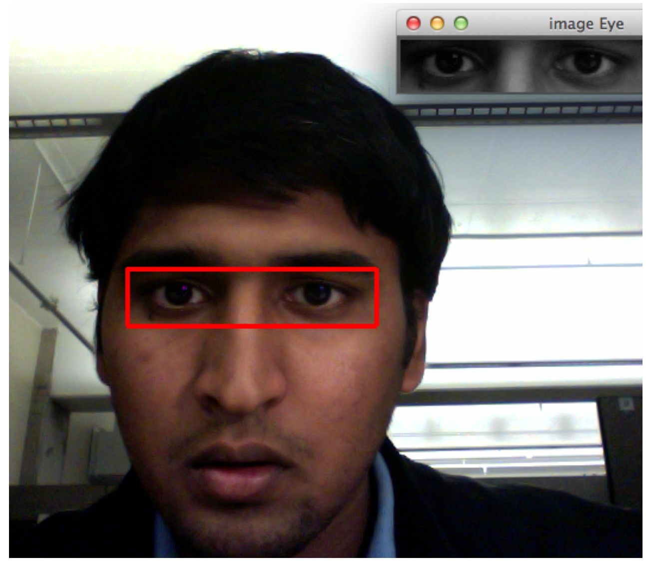


Figure 2: Face and Eye detection capture

On the software side, we make use of the front facing camera of an Android smartphone to capture the user's gaze as he/she follows the visual cues. The vision pipeline consists of an implementation of Viola Jones' face detection [8][9] using integral images and Haar cascade, followed by a Hough transform for circle detection [10] to track the user's iris. The vision algorithm is implemented in C++ using OpenCV libraries.

Because synchrony is key in the detection pipeline, data is recorded by synchronizing the LED strip with the smartphone over Bluetooth.

## 5. MEASUREMENTS

Below are the results of the iris position at different BAC levels.

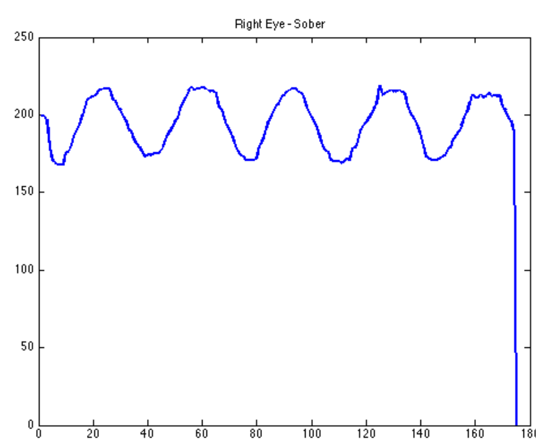


Figure 3: Iris Position at BAC = 0.00

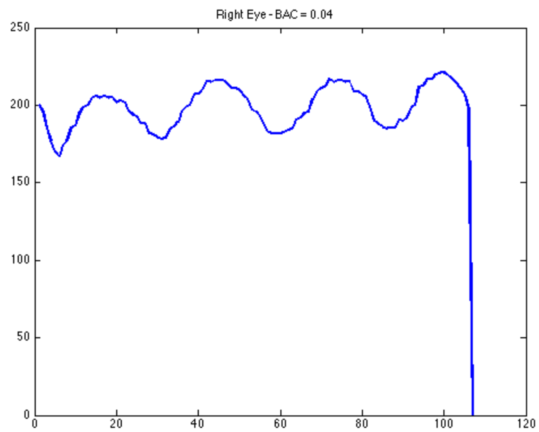


Figure 4: Iris Position at BAC = 0.04

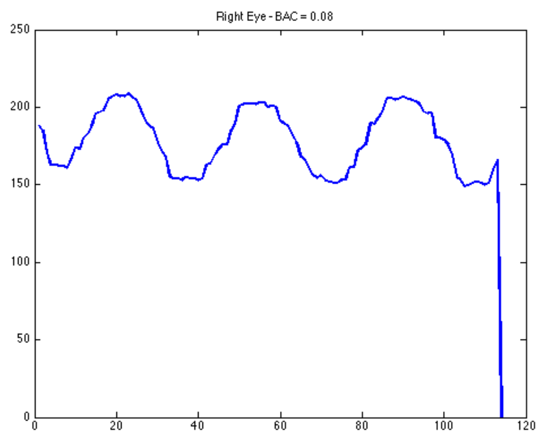


Figure 5: Iris Position at BAC = 0.08

We observe that the recorded data increasingly resembles a jagged sinusoidal wave with frequency $f_0$.

Note: The test subject has a BMI of 18.7 and had been fasting at the time of the measurements. BAC levels were monitored every 20 minutes with a hand-held breathalyser.

## 6. EVALUATION

The synchronization of the iris position with the sinusoidal sweep of frequency $f_0$ allows for the fast processing of the data. This is motivated by the observation that although a high intoxication level impacts visual response, the iris displacement due to nystagmus represents high frequency content compared to the underlying eye movement.

Taking the Fourier transform of the clean data (sober) will yield a strong frequency response at $f_0$, as shown in Figure 6. As the BAC level increases, more noise (jitter) is introduced in the frequency transform of the measured signal. This allows for classification of the user's state by detecting peaks in the power spectral density of the signal at higher frequencies.
Shifting detection to the frequency space represents a significant benefit since considerations of distance and alignment of the user with respect to the camera does not impact the sinusoidal frequency, thus facilitating the processing of the measured signal.

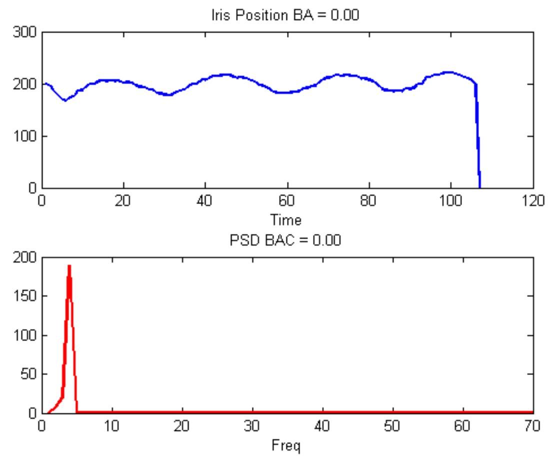


Figure 6: Iris Position and Power Spectral Density at BAC = 0.00

Figure 6 features one predominant peak at the sweeping frequency $f_0$.

## 7. FUTURE WORK

Optical flow [11] can be used to improve eye tracking over a sequence of frames in order to avoid losing track of the pupils. There exist other approaches to circle center computation, such as a modification of Förstner's algorithmm [12].
Because circle detection is more difficult when the iris is positioned at either corner of the eyes, an alternative measure of displacement can be explored by segmenting the iris from the sclera in the HSV color space. The ratio of iris area to the sclera area indicates the position of the eye, without the need for close tracking.

## 8. REFERENCES

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## 9. ADDITIONAL RESOURCES

[1] OpenCV http://opencv.willowgarage.com/wiki/

[2] Android Development http://developer.android.com/index.html

[3] Recorded data available at https://www.youtube.com/watch?v=39F3rIVLK4o