

CarSafe: A Driver Safety App that Detects Dangerous Driving Behavior using Dual-Cameras on Smartphones

Chuang-Wen You¹, Martha Montes-de-Oca², Thomas J. Bao¹, Nicholas D. Lane³,
Giuseppe Cardone⁴, Lorenzo Torresani¹, and Andrew T. Campbell¹
Dartmouth College¹, Autonomous National University of Mexico²,
Microsoft Research Asia³, University of Bologna⁴

you.chuang-wen@dartmouth.edu, martham@unam.mx, thomas358@gmail.com,
niclane@microsoft.com, giuseppe.cardone@unibo.it, {lorenzo, campbell}@cs.dartmouth.edu

ABSTRACT

Driving while being tired or distracted is dangerous. We are developing the CarSafe app for Android phones, which fuses information from both front and back cameras and others embedded sensors on the phone to detect and alert drivers to dangerous driving conditions inside and outside the car. CarSafe uses computer vision and machine learning algorithms on the phone to monitor and detect whether the driver is tired or distracted using the front camera while at the same time tracking road conditions using the back camera. CarSafe is the first dual-camera application for smartphones.

Author Keywords

Dangerous driving behavior, dual cameras, smartphones.

ACM Classification Keywords

H.4.0 [INFORMATION SYSTEMS APPLICATIONS]: General.

General Terms

Design, Experimentation, Performance.

INTRODUCTION

In 2010, 3,092 people were killed and 416,000 injured in accidents directly attributed to distracted drivers. Surprisingly, many people drive while tired or drowsy [3] and according to experts, many drivers fail to recognize they are tired or fatigued. Tracking dangerous driving behavior can help raise drivers' awareness of their driving habits and associated risks, thus, helping reduce careless driving and enforce safe driving practices.

In response to increasing accident statistics, the automobile industry is developing new driver safety technology for their top end cars. Research projects [1] conducted by automotive suppliers have integrated various advanced safety technologies (e.g., collision-avoidance, night-vision, and pedestrian detection systems) into luxury car models. By fitting various sensors into the vehicle (e.g., cameras, radars, and ultrasonic sensors), the vehicle can infer dangerous driving behavior, such as drowsiness or distracted driving.



Figure 1: CarSafe application is running on a smartphone (indicated by the red arrow) mounted on the windshield of an automobile.

However, only a tiny percentage of cars on the road today have these driver alert systems. And it will take a decade for this new technology to be commonplace in most cars across the globe. What do you do if you can't afford a top of the line car with all the safety extras? Several research projects have designed vision-based algorithms to detect drowsiness (using fixed mounted cameras) or road conditions (using smartphone cameras [2]). These solutions usually detect the driver's state or road information limiting inference to either the road or the driver but not both.

We propose CarSafe, the first driver safety and alert application that uses dual-cameras on smartphones as shown in Fig. 1. CarSafe fuses information from both cameras and others embedded sensors on the phone – such as the GPS, accelerometer and gyroscope – to detect and alert the driver to dangerous driving conditions in and outside of the car. How does CarSafe do this? Today's smartphones are not designed to process simultaneously streams from both cameras at the same time. To address this, CarSafe uses intelligent camera switching technology to schedule processing between two different camera classification pipelines at the right time. The front camera pipeline tracks the driver's head pose and direction as well as eyes and blinking rate as a means to infer drowsiness and distraction. Specifically, CarSafe uses blink detection algorithms to detect periods of micro-sleep, fatigue and drowsiness. If it detects this it alerts the driver by displaying a coffee cup icon on the phone's touch screen along with an audible alert. The back camera pipeline monitors the distance between cars to determine if the driver is too close to the car in front as well as tracking lane change conditions. If it detects that the driver is too close to the car in front a color status bar on the touch screen changes from

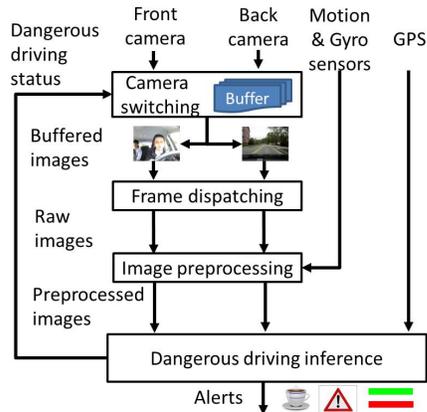


Figure 2: CarSafe system design.

green to red along with an audible alert. If CarSafe detects weaving across lanes on the road or other distracted or dangerous behavior it alerts the driver by displaying an attention icon on the phone’s touch screen along with an audible alert. So no matter how old your car is all drivers need is a smartphone and the CarSafe app to detect unsafe conditions. In what follows, we present an overview of the application.

CARSAFE – WHERE WE ARE

Figure 2 shows an overview of the CarSafe system design, which includes the following processing steps/modules: (1) camera switching, (2) frame dispatching, (3) image preprocessing, and (4) driving status inference. These four steps are described as follows. In the first step, *camera switching* buffers images captured from dual cameras using a camera-switching strategy. Most smartphones are equipped with dual cameras (i.e., front and back cameras). Because of the limitation imposed by current mobile platform designs (e.g., Android and iOS), only the foreground application can open a video stream at one time. To receive image streams from both cameras, applications must switch between these two cameras. However, camera switching incurs resource acquiring/releasing overheads (defined as a *switching delay*). Furthermore, as the application receives one image stream, the status monitored by the other camera is not tracked, thus becoming outdated. Therefore, to perform camera-switching operations at the right time, we design a camera-switching strategy that initiates a switching action as a result of receiving two types of triggers: (1) inferred status updates generated by drowsiness detection or road information monitoring modules, and (2) sensor triggers. Once CarSafe establishes a connection to a camera, it stores the retrieved images in a frame buffer for subsequent processing. Although CarSafe cannot continuously monitor both the road and the driver (note, it will require advances in the hardware and OS design to enable true parallel processing of both streams on the phone), it can track most of critical status updates on both sides by exploiting the camera switching strategy. However, this limitation will likely be eliminated as future generations of mobile platforms are introduced. In the second step, the *frame dispatching* module retrieves the most recent frames from the buffer for future preprocessing. Because of processing delays incurred by inference operations, some outdated frames are accumulated in the buffer while performing inferences. Therefore, after completing a round of oper-

ations detecting the driver’s state of drowsiness or monitoring road information, this step involves retrieving the latest frame (i.e., dropping outdated frames) stored in the buffer. This allows the overall system to be more responsive to real-time events.

The third *image preprocessing* step corrects for the orientation of the phone and execute illumination compensation on frames. Depending on the mounted position of the phone, the image might be tilted. By sensing the direction of gravity, the CarSafe determines the tilt angle (e.g., n degrees clockwise) of the phone in relation to the direction of gravity. This module rotates the receiving frames back (e.g., n degrees counterclockwise) to align with the direction of gravity. Furthermore, as the camera moves with the car, illumination conditions change. To compensate for changes in illumination, CarSafe generates preprocessed frames by performing histogram equalization on the raw frames for subsequent processing. In the final *dangerous driving inference* step, the current driving status is inferred by evaluating results generated by drowsiness detection, road condition monitoring (e.g., lane marks and following distance), and vehicle movement (e.g., turning direction and speed) sensing modules. Based on the inferred driving status, the CarSafe records the driving status and generate in-time alerts to drivers of dangerous driving behavior.

We prototyped the drowsiness detection module using Google Galaxy Nexus phones. Due to safety concerns, we pre-recorded video clips from three participants (one undergraduate and two graduate students). All participants took a 5-minute test to record all their blinks that occurred during the period by using a smartphone mounted in front of the participant. After completing the tests for all participants, we manually labeled the number of the long blinks for the subjects. Other blinks (blink durations smaller than or equal to 500 milliseconds – blinks greater than 500 milliseconds are deemed as indicating micro-sleep) were labeled short blinks. Based on the collected ground truth data, we calculate the total number of errors by aggregating all false positives and false negatives. The resulting detection accuracy of detecting long blinks is 85.71%, which is worse than the detection accuracy of detecting short blinks (88.24%), with an overall accuracy of 87.21%. While these results simply apply to the drowsiness detection for one camera we have implemented a near complete system processing both camera streams via switching. In addition, we are conducting additional experiments to validate the CarSafe system under real driving scenarios. For more information, check out a demo video on YouTube: http://youtu.be/tAd_sFhZT7w

REFERENCES

1. Volvos work within active safety. http://www.crp.pt/docs/A18S104-6_3_MariaFlink.pdf.
2. iOnRoad. <http://www.ionroad.com/>.
3. C. C. Liu, S. G. Hosking, and M. G. Lenne. Predicting driver drowsiness using vehicle measures: Recent insights and future challenges. *Journal of Safety Research*, 40(4):239–245, 2009.