DriveSafe: an App for Alerting Inattentive Drivers and Scoring Driving Behaviors

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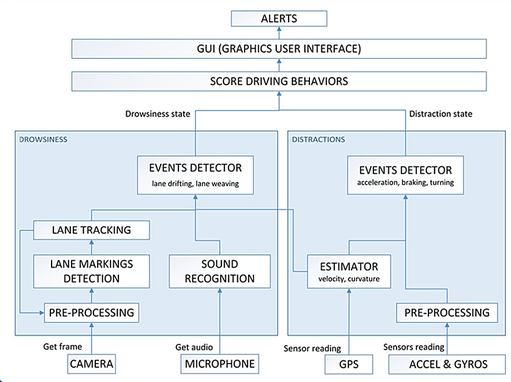
Problem Description

- Developing technologies to **detect inattentive drivers** is **essential to avoid vehicle accidents** and **to stimulate safe driving practices**
- **ADAS** are commonly fitted only **in top-end vehicles**
- In the **motor insurance sector consumers reject the Pay-As-You-Drive due to** the required installation of intrusive **"black-boxes"** in vehicles and their additional cost
- **DriveSafe** aims to **mimic some safety features** found **in** many **top-end vehicles** but using a commodity **iPhone**, and persuade insurers this app is an **interesting alternative to "black-boxes"**

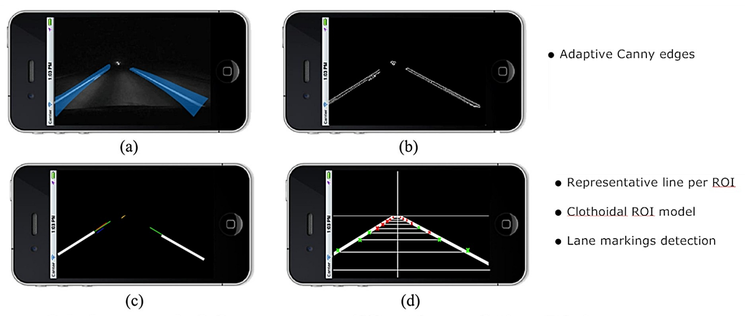
Overview

System Architecture

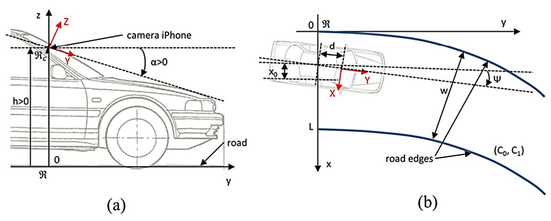


Drowsiness Detection

- **Based on vehicle lane position and lane changes** obtained by computer vision
  - Resize images to 320x240
  - ROIs in the gray scale images
  - Switching among calibration, initialization and detection
  - Adaptive Canny edges
  - Line detection by using Hough Transform
  - Representative line per ROI
  - Clothoidal ROI model
  - Lane markings detection



- **3D road and ego-vehicle model** from a modification of the Dickmans road model-base method



$$\theta = a\tan\left(\frac{h}{L}\right)$$
$$v = f_v \cdot \tan(\theta - \alpha)$$
$$L_{cv} = L + d$$
$$u = \frac{f_u}{L}\cdot\left(C_0\cdot\frac{L_{cv}^{\ 2}}{2} + C_1\cdot\frac{L_{cv}^{\ 3}}{6} - x_0 \pm 0.5\cdot w - L_{cv}\cdot\psi\right)$$

- **Lane tracking** using Kalman filtering $x = [C_0 \quad C_1 \quad x_0 \quad \psi \quad w]^T$
- **Event detector**
  - **Lane drifting: evaluate the driver's tendency to exit the lane.** Fraction of a given time interval (60 s) spent outside a virtual driving lane of around the center 1.2 m width
  - **Lane weaving: evaluates involuntary lane changes.** Based on the presence or absence of the directional indicator, the event detector module concludes whether a lane change is intentional or not

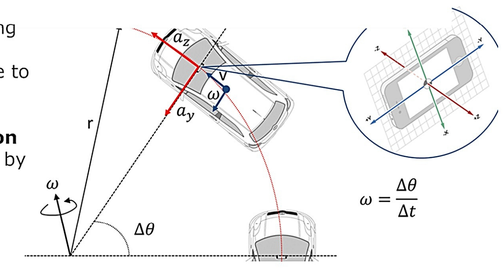
Distraction Detection and Score Driving Behaviors

- **Based on the frequency of critical driving events** considered as violations of certain thresholds imposed on vehicle acceleration measured by iPhone IMU
  - **Acceleration:** Abrupt positive peaks along the z-axis indicate aggressive increases of velocity
  - **Braking:** Abrupt negative peaks along the z-axis is indicative of harsh braking, and therefore indirectly of not retaining a minimum distance to the vehicle ahead
  - **Turning:** High lateral acceleration along the y-axis, points towards excessive velocity in left or right turns, and may result in the vehicle loosing traction

Event Type	Threshold sensitivity		
	Low	Medium	High
Acceleration	$0.1g < a_z < 0.2g$	$0.2g < a_z < 0.4g$	$a_z > 0.4g$
Braking	$-0.1g > a_z > -0.2g$	$-0.2g > a_z > -0.4g$	$a_z < -0.4g$
Turning	$0.1g < \lvert a'_y \rvert < 0.2g$	$0.2g < \lvert a'_y \rvert < 0.4g$	$\lvert a'_y \rvert > 0.4g$

- **Score driving behaviors**
  - **Raw measurements filtering** by Kalman filtering
  - **Hysteresis control** to avoid near activations due to the same event
  - Proposal for **decoupling the lateral acceleration due to the road curvature** from the one caused by wrong driver movements

$$a_y^c = \frac{v^2}{r} = r\cdot\omega^2 = \omega\cdot v$$



- **Event detector**
  - Drowsiness takes into account the mean and the standard deviation of Lane Drifting and Lane Weaving

$$Score_{Drow} = 1 - \left(\left(\frac{m_{LD} + \sigma_{LD}}{2}\right) + \left(\frac{m_{LW} + \sigma_{LW}}{2}\right)\right)$$

  - We score the indicators taking into account the number and intensity of the events detected per Km

$$Event\_km_e = \left[\left(k_1\cdot Low_e + k_2\cdot Medium_e + k_3\cdot High_e\right)/Km\right]$$
$$Score_{Dist_e} = 1 - CDF_e\left(Event\_km_e\right)$$

Experimental results

- **Test-bed**
  - **12 participants** (9 males and 3 females) of our Lab
  - The **test vehicle** was a **Renault Laguna** with manual shift
  - **Each participant** carried out the **two tests (aggressive and normal)**, **20 min long** each one, in **different days** and varied daytime (4 at morning, 4 at afternoon and 4 at night) and with **different weather conditions**: 20 mainly bright and sunny, 2 raining and 2 foggy
  - **Aggressive driving** under controlled vehicle maneuvers: 2 x lane drifting, 6 x lane weaving, 4 x sudden acceleration, 6 x sudden brake and 2 x sudden turn
  - **Normal driving**, which contains data collected during everyday driving routines

TABLE II. EVENTS DETECTION PERFORMANCE. TRUE POSITIVES (TP), FALSE POSITIVES (FP), GROUND-TRUTH (GT), PRECISION (PR), RECALL (RC)

Event	TP	FP	GT	PR	RC
Lane Drifting (LD)	25	3	25	0.89	1.00
Lane Weaving (LW)	75	6	78	0.93	0.96
Acceleration (AC)	51	19	58	0.74	0.88
Braking (BR)	80	20	91	0.80	0.88
Turning (TN)	28	10	30	0.74	0.93
Overall	260	57	282	0.82	0.92

TABLE III. COMPARATIVE DRIVING BEHAVIOR EVALUATION.

	Normal driving				Whole subjective score (%)	
	Detections		Score (Mean)			
Event Type	DS	AXA	DS	AXA	DS	AXA
Acceleration	12	15	8.85	6.37	62.50	37.50
Braking	13	11	9.92	7.27	87.50	12.50
Turning	8	28	8.10	6.18	80.00	20.00
	Aggressive driving					
	Detections		Score (Mean)			
Event Type	DS	AXA	DS	AXA		
Acceleration	58	56	4.54	5.00		
Braking	87	80	4.73	3.70		
Turning	30	58	3.60	2.20		

Conclusions and Future Works

- **DriveSafe, a new driver safety app for iPhones** has been presented
- **First app** that **detects inattentive driving behaviors and scores driving style** at the same time
- **Quantitative evaluation** based on a **controlled test-bed** in **real scenarios** has been carried out from 12 drivers
- **Detection performance** of some **inattentive driving events** reached an **overall precision of 82% at 92% of recall**
- Driving scores comparison **DriveSafe vs AXA Drive app** obtained a **better valuation for DriveSafe**
- **Future guidelines**: upload Drivesafe version 2.0 to the Apple store after deeper tests with more vehicles, roads and users

Acknowledgments

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