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Driver Head Movements While Using a Smartphone in a Naturalistic Context

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Summary

Smartphone usage while driving is a dangerous activity directly linked to 17% of deadly accidents in France in 2015. While it can potentially impact every road user, professional drivers are perhaps the most affected collective as they spend a high amount of time in their vehicles on a daily basis, whether they deliver goods or transport people. Detecting smartphone usage is interesting for many reasons, from legal controls to forensics investigation in accidents, without forgetting the possibility of alert the driver of the danger he is engaging in.

In this study we evaluate the pertinence of using driver head rotation movements to automatically predict smartphone usage at the wheel. In order to fit the system to the particularities of professional drivers, a naturalistic driving study have been conducted. 15 operational vehicles from two private French transport companies were equipped with near-infrared cameras, embedded real-time computer vision and machine learning techniques.

Common behavioural patterns have been revealed. Head rebounds are a constant (letting the driver switch gaze between the road and the device). Additionally, the duration a driver spends looking down from a reference neutral direction can be used as a reliable parameter to predict smartphone usage. On the other hand some divergences between van and bus drivers head movements have been noticed.

A real-time smartphone usage detection system has been implemented from the results of this study. Preliminary results are encouraging and a prototype of the system is already being tested by professional drivers in a naturalistic context.

Background

Studies over the years have demonstrated that speaking on a cell phone while driving introduces a cognitive distraction that levels up the risk of having an accident. Smartphone usage at the wheel creates new threats as most of the tasks require the user to be looking at the screen and consequently to pay less attention to the road. According to a recent survey from the ASFA in France [1], 20% of drivers admitted to text occasionally while driving, 33% to check their notifications frequently and 57% to speak on their handheld device. A field study from Zendrive [2] has revealed that drivers in the US use their phones in 88 of every 100 trips. Some researchers have estimated that the risk of having an accident is 8 to 23 times higher when looking at a phone, and deadly crashes linked to this behaviour have risen from 4% in 2010 to 17% in 2015.

Objective

The Toucango project, carried out by the company Innov+, intends to build a portable Advanced Driver Assistance System (ADAS) to automatically detect, based on real-time video analysis, different kinds of drowsiness behaviours and driver distraction, including smartphone usage. Whenever one of these events is detected, an alert is sent out to the driver. The system keeps track of all events in order to be used in data analysis campaigns.

The purpose of this study is the evaluation of whether video analysis of driver head movements can constitute a fast, reliable method to be applied in real time smartphone usage detection. We intend to verify two main hypothesis:

- If differences between head movements while using a smartphone and when driving normally are significant enough to be considered as a parameter to be used in identifying both behaviours.
- If head behaviour while using a smartphone is different between bus and van drivers.

Methods

A naturalistic data acquisition campaign has been carried out by Innov+ with the collaboration of its partners, taking place in different stages between March 2015 and February 2017. 15 operational vehicles were equipped with portable devices carrying a near-infrared camera and a GPS tracker. In order to avoid calling up the attention of the driver, the devices were mounted on the dashboard, set in a lateral angle maximizing the framing of the driver's face but completely out of his/her vision field. Both employers and employees agreed that the data would remain confidential and no questionable behaviour would be reported.



Figure 1 – Device's set up in a van (left) and in a bus (right)

Two companies participated in this study: a distribution company working with medium-size vans that delivers sensible items such as medical products or confidential documentation, and a passenger transport group covering long-distance commercial lines in buses, within France and the EU.

Videos were recorded at 30 fps and at 640x480 pixels, with artificial near-infrared illumination. Trips were filmed at day and night, with natural changing lightning conditions. 15 drivers from different ages, sex and ethnicities participated in the study. For the particular purpose of smartphone detection, we selected 148 hours of footage (53 hours of videos from vans and 95 hours from buses), from which 122 sequences of drivers using a smartphone (87 from vans and 35 from buses) were manually extracted. Length of every considered sequence was fixed to

300 frames (10 seconds). We then manually quantified driver head rebounds (gaze switching between the windshield and the smartphone) in every video sequence.

We also created a collection of non-texting driving videos, composed by an equal number of sequences recorded under the same conditions and with the same length, in which subjects were driving normally. Computer vision techniques were applied to the dataset in order to track driver's facial landmarks with a 68-point model. From it, 3D head rotations were modelled by estimating Euler angles: yaw (rotation around the vertical axis), pitch (rotation around the lateral axis) and roll (rotation around the longitudinal axis). Neutral head pose, defined as the orientation of a driver's head when looking at the road, was estimated with machine learning techniques and manually checked.

Results

Drivers engaging in a secondary task that requires their attention need to switch gaze between the windshield and the element that constitutes the secondary attention source, and consequently they present fast, repetitive head rebounds. This is applicable for tasks related to driving (such as looking at rear-view mirror or checking a GPS device) or completely independent (setting up a sound device, reading papers). Regarding the particular case of smartphone usage, the main difference stands in a considerably higher density of movements within pitch rotation component, which represents vertical head shifts.

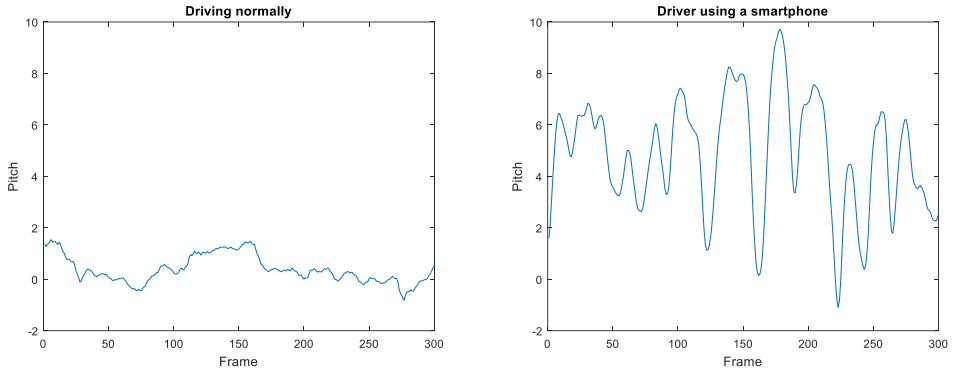


Figure 2 – Pitch rotation (in degrees) while driving normally (left) and when using a smartphone (right)

The distraction was quantified by evaluating the number of head deviations of more than 5° in the pitch component from neutral pose (an augmentation of pitch value from the reference means looking down). An analysis of the variance (ANOVA) found a highly significant effect of this parameter between the two classes of sequences ($F=102.62$, $p<0.0001$). Post-hoc HSD Tukey tests indicated that the means of both groups are significantly different ($q=135.83$, $p < 0.0001$). Mean percentage of time drivers spend looking down when texting is 49.23% for 9.02% when they are driving normally.

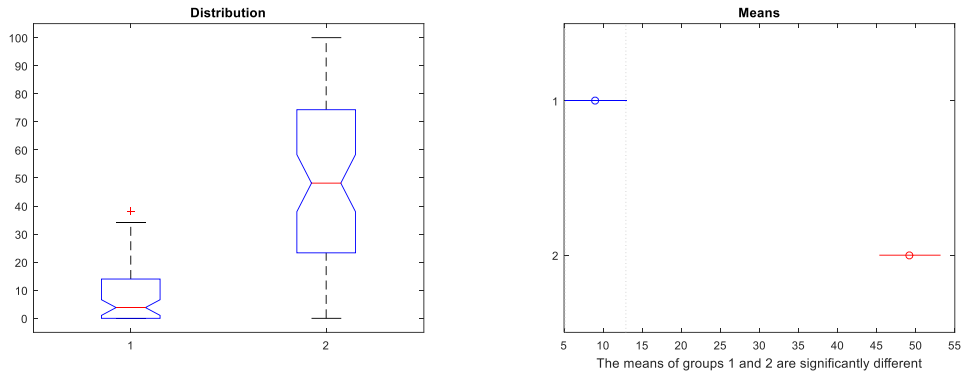


Figure 3 – Percentage of time looking down while driving normally (1) and when using a smartphone (2)

We observed some differences between bus and van drivers behaviour. Bus drivers tended to hide their smartphone in order to avoid being seen by the passengers, and usually placed the device low and aside. Therefore they presented a low frequency of head rebounds (one every 2.12 seconds), which covered a wide vertical range (mean of 33°). On the other side, van drivers adopted a position where they could shift gaze faster, thus they placed their smartphone nearer the wheel and at a higher height. They presented a higher frequency of head rebounds (one very 1.2 second), covering narrower vertical range (mean of 12°).

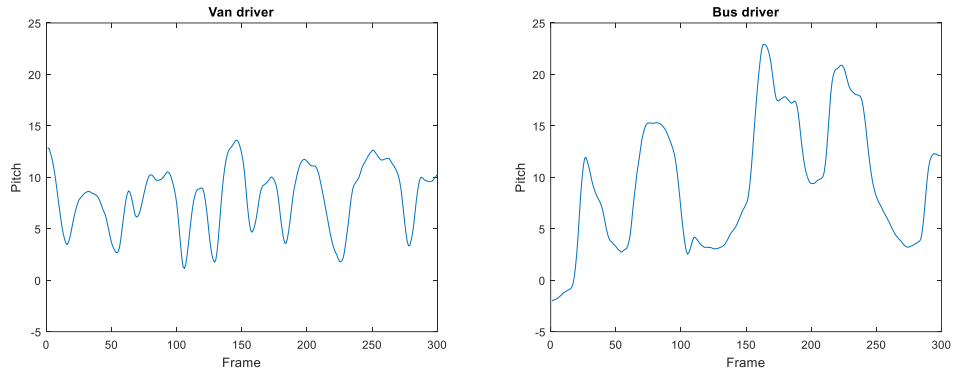


Figure 4 – Pitch rotation (in degrees) while using a smartphone in a van (left) and in a bus (right)

Regarding head behaviour within pitch rotation component, a One-Way ANOVA found no significant effect in the percentage of time van and bus drivers are looking down when texting ($F=1.37$, $p<0.2472$).

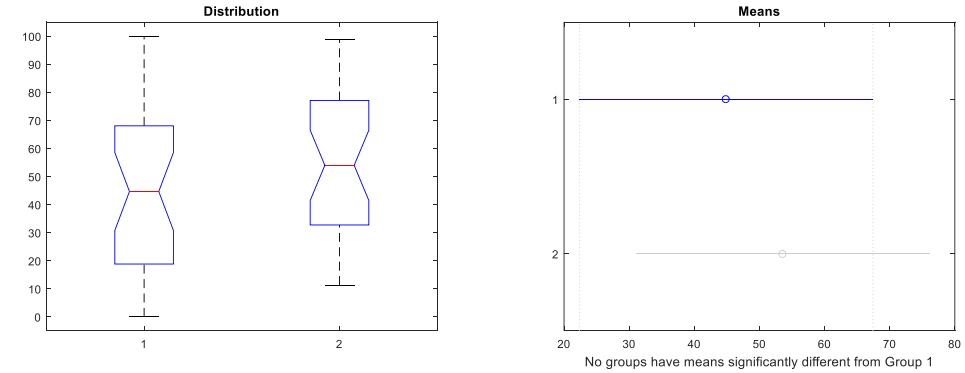


Figure 5 – Percentage of time looking down in van (1) and bus (2) drivers using a smartphone

Discussion/Impact

We have demonstrated that video analysis of head movements can be used to detect driver smartphone usage. Head rebounds are an indicator of the driver engaging in a secondary task and looking down too often is a particularly non-standard behaviour directly linked to smartphone usage.

We also found some divergences between van and bus drivers behaviour, which are coherent with the context. Bus drivers seem to be more concerned about using the smartphone at the wheel. Some explanations may be the need of hide their smartphone or the added responsibility of transporting people. However, we noticed than amongst the drivers who participated in the study, van ones are younger than bus ones, which could also have an influence on the perception they have of the danger engaged by smartphone usage at the wheel. Further tests should be carried out implying a bigger population.

A real-time smartphone usage detection system based on video analysis of head dynamics has been implemented from the results of this study. It performs real-time video analysis of driver's face, evaluates head rotation deviations from neutral orientation when the driver is looking at the road, and detects if the percentage of deviations exceeds a threshold. Preliminary tests have been carried out on the test dataset with encouraging performance (accuracy of 84%) and then in a driver simulator with even better results. In order to further evaluate the considered model, the system has been deployed in several experimental Toucango devices. First evaluation of this algorithm performance under real world conditions will take place in the upcoming weeks.

As we only used head movements, some other behaviours may be confused with smartphone usage, such as consulting papers or manipulating an embedded navigation device. However we consider them to be equally dangerous as they are diverting driver's attention from his/her main task.

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