Positioning and design of a in-car camera system for monitoring driver's state, inner cabin and outer traffic with data analysis purposes

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Introduction

Vision-based driver-assistance systems (VBDAs) have emerged as a significant contribution for the improvement of Advanced Driver Assistance systems (ADAS), and have had gradually gained a substantial meaning in people's life: every year approximately 1.35 million lives are truncated as a consequence of road traffic crashes. Moreover, between 20 and 50 million people (depending on year and country) undergo non-fatal injuries, including sometimes disabilities as an outcome. [1]
Nowadays car accidents and related deaths represent a daily occurrence because of other's people carelessness (driver's drunkness, drowsiness, sudden illness), and as several studies show, over 90% of traffic accidents are caused by a human error [1, 2]. Machines, however, are more reliable and consistent and they commit far less mistakes when programmed properly, and therefore they can prevent most of those aforementioned fatalities.

This paper covers designing, developing and manufacturing a smart camera system for a Ford Focus 2018 that is able to monitor both outer and inner conditions. Development includes researching the topic to design and produce a competent solution for a camera system that is a consumer level product, which means that mountings and wiring are implied to car's original wiring as good as possible. An onboard computer for the system is located in the trunk and wiring is done in a way that all the cameras are plugged in with a single universal cable. The monitoring system is capable of detecting 360° surroundings of outside of the car (tracking other traffic, pedestrians, etc.), as well as inside of the car by monitoring the drivers state (drowsiness, sudden illness, etc.) and objects not supposed to be in car.

Therefore, this project is motivated by the strong willingness of assuring safety and comfort behind the wheel, that concerns both drivers and passengers, and vulnerable road users: pedestrians, cyclists, and motorcyclists.

Driver assistance systems (DAS) have developed from anti-lock braking systems (ABS) in the 80's and Electronic Stability Control (ESC) in the 90's to modern self-parking and collision avoidance systems in the recent decade. In most recent years, these systems have evolved to fully autonomous driving systems, and nowadays every major vehicle manufacturer are developing them. Most of the manufacturers have at least prototypes, while several of them have included some level of autonomous driving even in consumer markets. [3]. In recent decades advanced driver assistance systems (ADAS) have been taken into account as vehicle's detectors, benefitting from computer vision technologies especially in terms of costs: an active sensor - that is, laser or radar sensors - is way more expensive than an optical one - for instance CMOS and CCD ones [4]. Especially laser based LiDARs (Light Detection and Ranging) have been popular in autonomous driving solutions, due to their efficiency and high accuracy, but due to their price, some manufacturers see purely optical sensors as a more viable solution [5].

This project aims for applying affordable aftermarket vision to the vehicle, and therefore optical sensors (cameras) and computer vision technologies seen in [4], [6] and [7] are going to be closely related to this project's implemented solution. Early solutions in 360° camera systems in [8] and [9] represents the general guideline for 4 outside camera placements, where side view cameras are attached to the side mirrors, and one camera is headed to front (bumper/dashboard), and one is located in the back for rear view. Driver's state can be monitored using camera and machine vision as seen in [6], [7] and [10], and especially these detections focuses on monitoring drivers eyes, because it's most easily detected and most consistent sign of human's tiredness.

Many aspects in vehicle camera systems are based on object detection, which is computer technology related to image processing and computer vision. Detection system that is going to be applied to this project is close to YOLOv3, which represents a state-of-the-art, real-time object detection system that can detect over 9000 object categories applying a convolutional neural network [11]. YOLOv3, which stands for version n. 3, benefits from few shrednesses as multi-scale predictions and an enhanced backbone classifier with the purpose of performance improvement. The approach used by its developers is the application of a single neural network to the full image. The network splits the image into defined areas, thus predicting probabilities and boundaries for each region [12]. Advantages of this system includes improved rapidity with respect to other systems, because it is 1000x faster than R-CNN and 100x faster than Fast R-CNN [11][12].

Methods

Our camera system has been designed in order to provide a 360° surround outer view and an inner monitoring conditions' view. It has been tested on a Ford Focus 2018, even though it is applicable to each vehicle in use. In order to decide which combination of positioning, angle, number and type of camera would have been the most suitable in terms of costs, efficiency, data processing and blind spots minimization, we started using a Denver ac5000w action camera, with the following properties: full HD, Wi-Fi function, 5 Mpixel CMOS sensor, 120° fixed angle, recording up to FULL HD 1080P.

The initial purpose was to understand mainly angles and positioning, thus the car was driven outside in order to have enough space around the vehicle and to take snapshots with the Denver ac5000w action camera. First task was to decide whether or not the system had to include either a single front facing camera, or a couple of side cameras to be combined to create the front view. Experimenting with the camera positioning gave an estimation of what angles could be achieved from each location of the car. We used traffic cones to have a rough estimation of measurements from which to derive angles of view. A computer was used to monitor the camera view from its bigger screen, through the application provided by the camera company itself.
It was noticed that the front view presented negligible blind spot areas. In fact, the optuse angle that a fixed focus camera would create from the front, would leave a very small area not monitored, which is not important for the scope of this project: surveilling traffic outside the car does not require a very close frontal view, but rather an overview of what surrounds the camera.

Regarding the inner camera view, a first try was made with Denver ac5000w action camera, even though a camera with 120 degrees fixed angle was not suitable to give a total overview of the interior of the vehicle. Consequently, we opted for a wide-angle camera

The cameras we ordered had the following specifications:

- ELP Aptima 5Mp 170deg usb camera x1 (fixed focus camera)
- ELP 720p 120deg usb camera x6 (wide angle camera)

Outer monitoring

The best solution in terms of number of cameras (and consequently cost), data processing and blind spots minimization for the outer monitoring the following:

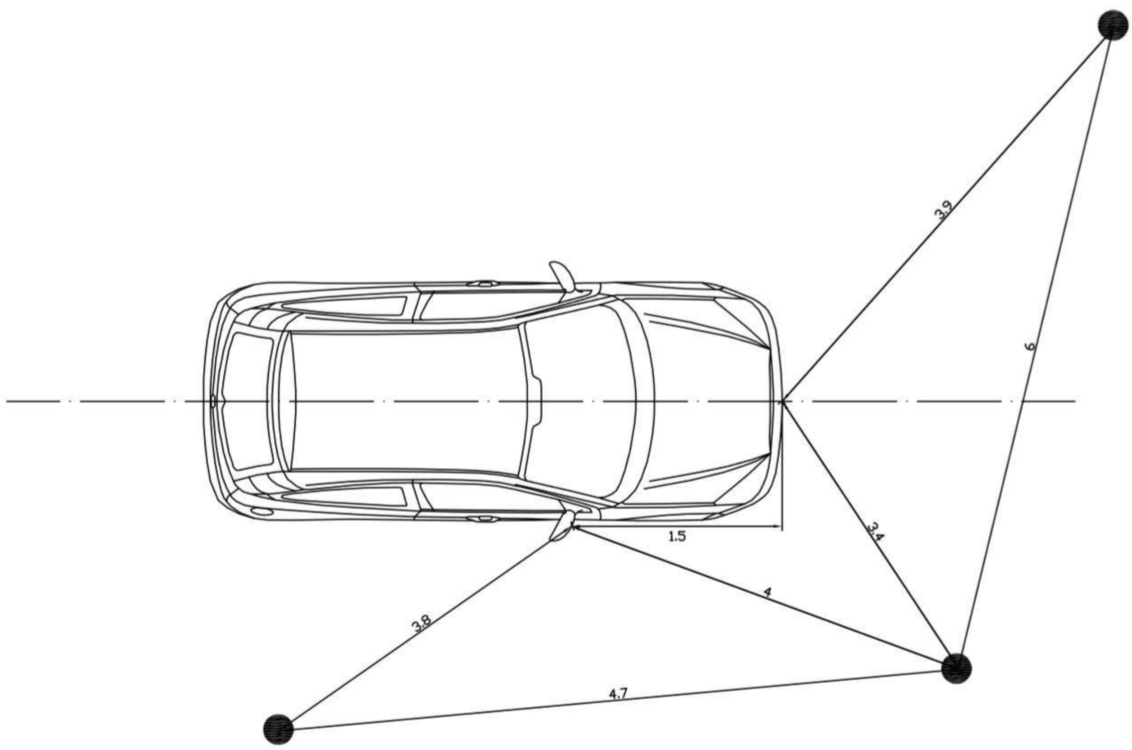
- Two ELP 720p 120deg usb cameras mounted on side mirrrors
- Two ELP 720p 120deg usb cameras mounted on rear window trim
- One ELP 720p 120deg usb camera mounted on rearview mirror from the inside

Inner monitoring

One ELP Aptima 5Mp 170deg usb camera is installed in line with the inner back handles.

Plastic parts are 3d-printed in order to obatin a well designed final product, with an optimal consumer grade. Plastic parts are modified in order to install the cameras, aided by 3D printed parts to get an aesthetically pleasing final product.

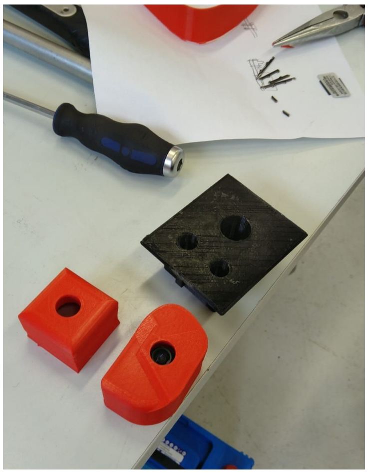
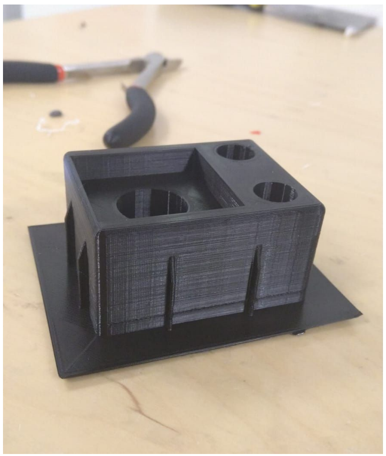
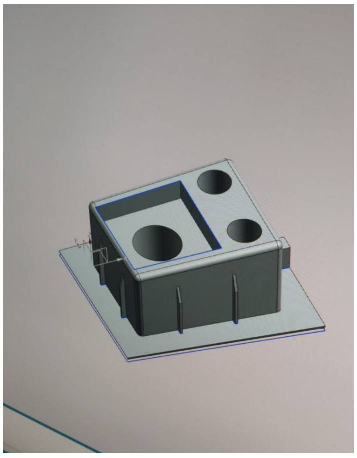
- Measurements
- Angle of view coloured in yellow and labelled
- Blindspots coloured in black and labelled
- Bisector of the yellow angles, indicating where the camera lens is pointing to
- Height of the cameras with respect to the ground
- Simmetric sides for the view angle (for example not 3.4, 3.9m in the figures but rather 3,4 and 3,4 m)
- Legend (cameras and cones labelled or numbered)



And for the inner cameras

- Height of the cameras with respect to the ground
- View of the inner cabin and reference measurements to allocate where the camera is installed
- A top view for the inside (similar to the one for outside), with similar features discussed before

Manufacturing of the camera housings was done with 3d-printer.

Results

(This is just a sketch)

- Outer and inner monitoring for a 360° car camera view
- Designed consumer product
- Wiring
- Real time 360 view displaying (panoramic view in the same screen)

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