A camera-based system to detect driver hands on the steering wheel in semi-autonomous vehicles

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Abstract. Semi-autonomous vehicles require monitoring the driver to check if he is supervising the system and/or ready to take over. Most cars rely on steering-wheel sensors to detect hands and do not monitor the non-driving related task the driver might be performing. We present a camera-based system with a multi-branch architecture, which provides the number of hands on the steering wheel, on a tablet representing a secondary task and the tablet position. It also tackles a common issue with other camera-based systems: a free hand in front of the steering wheel can be classified as grasping it. Moreover, our system deals with cases when the driver might use a tablet on the steering wheel, as he is allowed to do in autonomous mode. These two points are critical to assess the time the driver will need to take over. Finally, combining both steering wheel and camera systems would also make vehicles harder to trick and therefore safer.

Video available at: https://www.youtube.com/watch?v=qfYOM4sdWr4

Keywords: Driver monitoring, Deep learning, Hands on steering wheel.

1 Introduction

Before the advent of fully autonomous vehicles, the driver will still have to supervise the car and/or to take over the control, in order to deal with situations that the car cannot resolve. In such semi-autonomous cars, it is critical to monitor the driver, to know if he is ready to take over, with his hands on the steering wheel, or if he is engaged in a non-driving related task.

In this work, we place ourselves in the scope of such vehicles and show a system to detect if a driver has his hands on the steering wheel or on a tablet (representing the non-driving related task). An increasing number of vehicles integrate hands detection systems embedded in the steering wheel. Such systems can prove very reliable under most of the situations. However, we intend to show that camera-based systems can complement steering wheel-based systems and are critical in specific situations.

Numerous work address the detection of hands on the steering wheel with a camera. One of the most direct approach is to classify the entire image captured by the camera, like in [1], however we found it did not perform well with a small database. Systems similar to those described in [2] and [3] rely on object detection. They first detect the

steering wheel, then the hands and finally determine whether the hands are on the steering wheel or not, based on their joint area. These systems have limitations, because if a hand is masking the steering wheel and not touching it, it might be classified as grasping the steering wheel. In [4], the model relies on a first object detection to detect the driver hands, and then segments them. Finally, it classifies the hands state between grasping the steering wheel, the mobile phone or no object. Such a system should distinguish between a hand grasping or overlapping the steering wheel. However, it doesn't use the rest of the image and the steering wheel and hands positions to perform the final classification. We intend to tackle these limitations with the proposed method.

2 Proposed system demonstration

2.1 System description

Our system consists of:

1. a steering wheel with grip sensors detecting the hands and the gripping force
2. a tablet, on its stand, on the right of the steering wheel
3. a color camera pointing towards the steering wheel and the tablet
4. a PC executing the software which processes the camera images and the grip sensor signals to output information about the driver current behavior in real-time

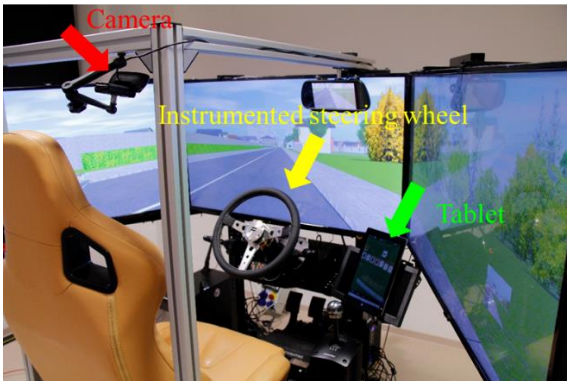

Fig. 1. The system set-up, with the steering wheel, the tablet and the camera

The software executes two models in real-time:

1. a decision tree algorithm, which processes the grip sensor signals and outputs:
   a. the hands position on the steering wheel
   b. an indicator of the gripping force
2. a deep learning model, which processes the camera images and outputs:
   a. the number of hands on the steering wheel
   b. the number of hands on the tablet
   c. if the tablet is on its stand or held by the driver

The deep learning algorithm has a multi-branch architecture: first an encoder as a common trunk and then three branches, each dedicated to one of the three tasks described above. To improve this model, we added a fourth branch which identifies the most relevant zones in the image [5]. The advantages of this approach are that we use the entire image (the position of the relevant elements is as critical as their appearance) and the shared information between tasks (if a hand is on a tablet, it is not the steering wheel).

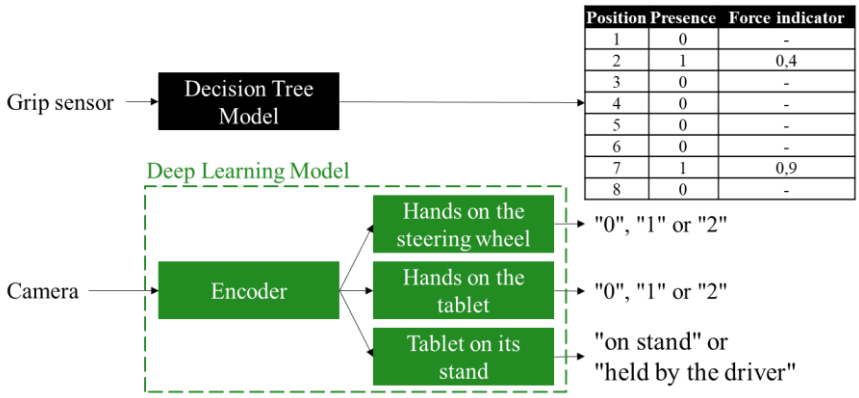

Fig. 2. Models of the system

2.2 System in action

In **Erreur ! Source du renvoi introuvable.**, we present four cases of hands detection by our system. Cases a) and b) are simple cases where most of the existing system would give accurate results. In c), most camera systems would detect that a hand is on the steering wheel even if it is only masking it. In d), the driver uses the tablet on the steering wheel. A steering wheel sensor might detect the hands but our camera system would detect the tablet usage.

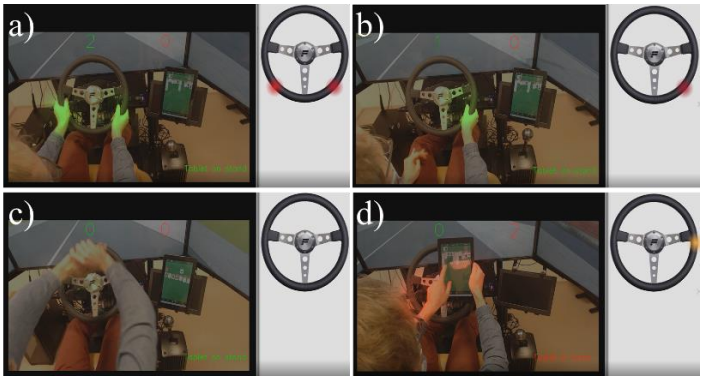

Fig. 3. Examples of hands detection by the system

3 Conclusion

We describe here a system showing the complementarity of the sensitive steering wheel and the camera-based systems. Both systems runs in parallel. Future works should focus on merging the two outputs and validating on an embedded platform with a larger database. However, we show the advantages of using a camera-based system: both systems back-up each other, the camera-based system tells if the driver is engaged in a secondary task and if the driver uses a tablet on the steering wheel. Our model also makes the difference between a hand grasping the steering wheel or occulting it. Finally, considering that most of steering wheel-based systems can be tricked [6], adding an extra verification would make semi-autonomous vehicles more secure.

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