Sensor fusion and human behavioral pattern analysis for vehicle occupancy detection

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1. Abstract
Context sensitivity is a key feature in modern vehicles, which includes seat occupancy detection. Current systems are prone to misdetection or are sometimes non-existent as for rear passengers. Our approach is to look at human behavior while getting into, sitting inside and getting out of a vehicle. Occurring sensor patterns, including door opening and closing, damper and seat movement and seat belt use are analyzed and fused. These sequences are then modelled by a Dynamic Bayesian Network. Over 360 cases including more than 50 subjects are recorded and used for training. A 10-times cross validation is performed which gives an overall accuracy of above 90%.

2. Summary
Most of today’s cars are not aware of their inner context, especially how many people are in the car and where they are sitting. Seat occupancy detectors in the seats are mostly in the front passenger seat and only able to detect weights above a certain threshold. This is to fulfill requirements for example set by the Euro NCAP [5] for seat belt reminders but with a focus on cost reduction. Therefore, luggage on the passenger seat can already activate the seat belt reminder.

A car’s awareness of actually occupied seats could enhance certain functions like air conditioning. Only occupied seats need to be air conditioned which would reduce the waste of energy and therefore lead to higher fuel efficiency.

Improved seat sensors are available [3], but still fail if a person is not sitting correctly in the seat and are more expensive. Other sensors like cameras have also been used to improve occupancy detection [1,2]. This work aims at using already build in sensors and fusion their data to better discover the state of occupancy, considering human behavioral patterns while getting into and out of the vehicle, as well as sitting inside of the car.

Terroso-Sáenz et. al [4] showed a way to use discovered patterns for getting into and out of the car by applying a state machine. However, this approach lacks of flexibility and important sensors and is prone to behavior which is not modeled by their state machine.

We apply a Dynamic Bayesian Network (DBN) to fuse given input data to detect seat occupancy. For this purpose, human behavior for entering and leaving the car was analyzed for over 360 cases, including more than 50 subjects, in most of which the subjects weren’t aware of the analysis and thus behaved normally. A highly reoccurring pattern is shown in Figure 1. Here the activities when a passenger is getting into the vehicle are visible.

Figure 1. Sensor signals while a passenger gets into the vehicle, with the moment of sitting down indicated by the vertical red lines.
First, the door is opened (black), afterwards the suspension, i.e. the dampers are shortened (brown, blue, red yellow) while simultaneously the seat occupancy sensor is activated (grey). Next, the door is closed, followed by seat adjustment (light green) and finally the seat belt is locked (light blue). This pattern is similar for over 80% of the recorded cases with only minor differences. Main differences are timing and order and availability in the sequence. In Figure 1 the door was opened and closed once before, but the seat remained empty. Thus, fusing the sensors and looking at the identified pattern is key to occupancy detection. While a person is inside the car, the focus is on sensors as window handle, HMI button presses and climate adjustments. This further improves the probability of an occupied seat and reduces misuse. For detecting a person leaving the car, similar sequences to a person entering the vehicle are used.

The system is validated by 10 times cross validation and against cases with luggage on the passenger seat. An overall detection rate of over 90% shows promising results. Future work will aim at detecting border cases like subjects changing seats while driving and distinguishing luggage from empty seats. New sensors like cameras will be fused with the existing model therefor.

References


