RoadLab: An In-Vehicle Laboratory for Developing Cognitive Cars

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Abstract

World-wide deaths from injuries are projected to rise from 5.1 million in 1990 to 8.4 million in 2020, with traffic-related incidents as the major cause for this increase. Intelligent, Advanced Driving Assistance Systems (i-ADAS) provide a number of solutions to these safety challenges. We developed a scalable in-vehicle mobile i-ADAS research platform for the purpose of traffic context analysis and behavioral prediction designed for understanding fundamental issues in intelligent vehicles. We outline our general approach and describe the in-vehicle instrumentation. We present a number of research challenges and early results, as we outline future directions.

Layered Approach to Intelligent Vehicles

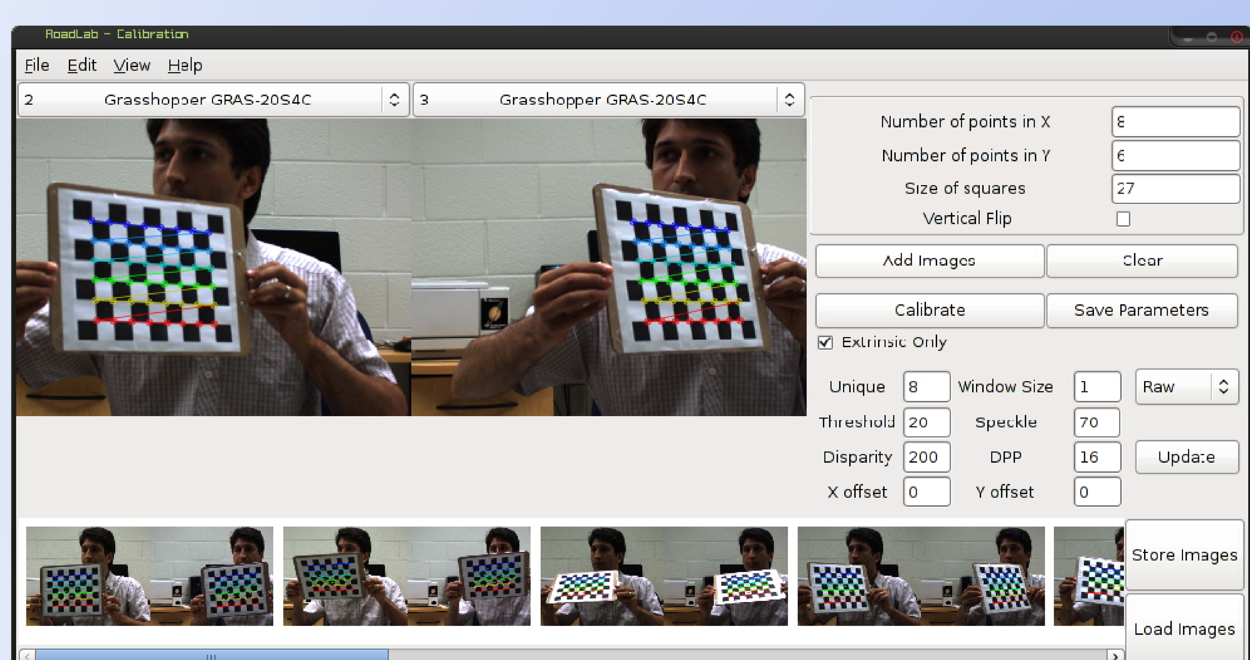
Our proposed computational model consists of four layers, with increasing levels of data abstraction

- The innermost layer consists of the hardware and software required to capture vehicle odometry, sequences from visual sensors, and driver behavioral data.
- The second layer pertains to hardware synchronization, calibration, real-time data gathering, and vision detection processes.
- The third layer is where the data is transformed and fused into a single 4-dimensional space (x,y,z,t)
- The last layer makes use of the fused data to compare driver behavioral data with models of behavior that are appropriate given current odometry and traffic conditions.

Camera Calibration

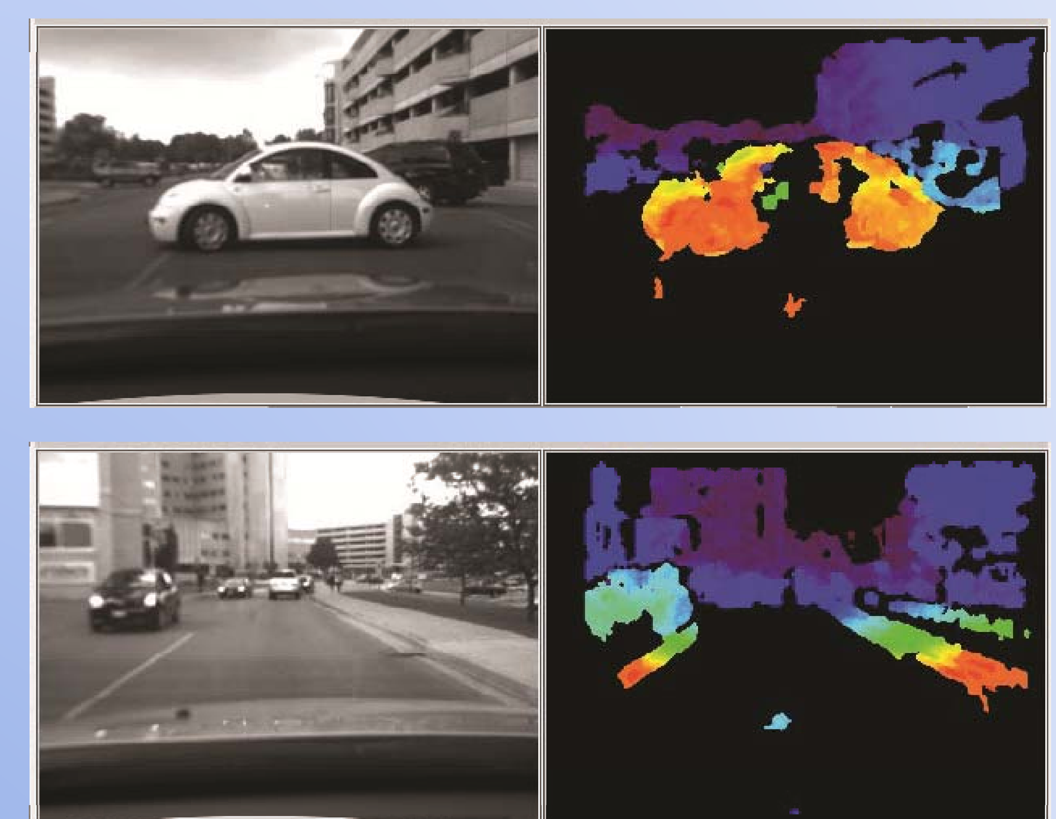
For visual sensors, it is critical to obtain precise calibration parameters such as lens distortion, the optical center, and the external orientation of sensors with respect to each other. The RoadLab stereo calibration interface was designed for this process (see Figure below).

The calibration process consists of two steps. Intrinsic parameters are first estimated for each sensor and then, based on these, the extrinsic parameters for all possible sensor pairs are obtained.



Stereo Depth Computation

All the image frames from visual sensors are synchronized to within 125 μs. Once the synchronized frames are obtained, stereo depth maps are computed at frame rate, based on the calibration parameters (see Figure below)

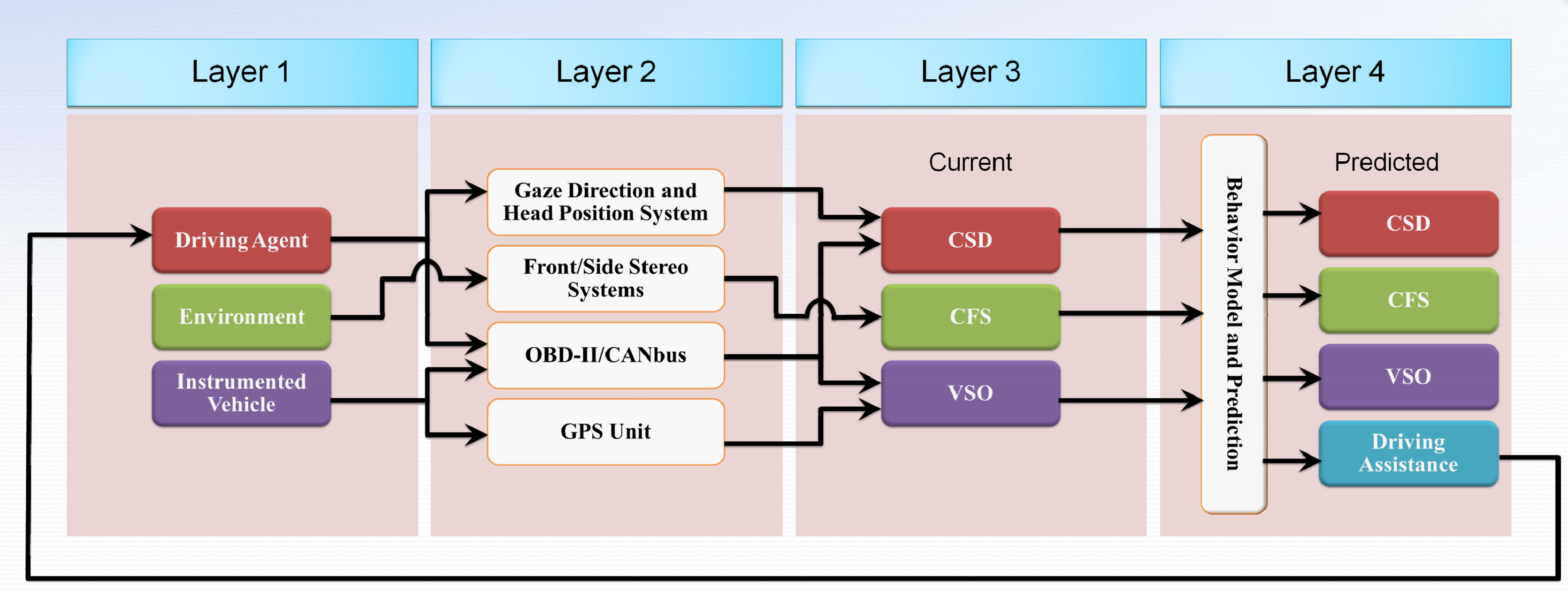


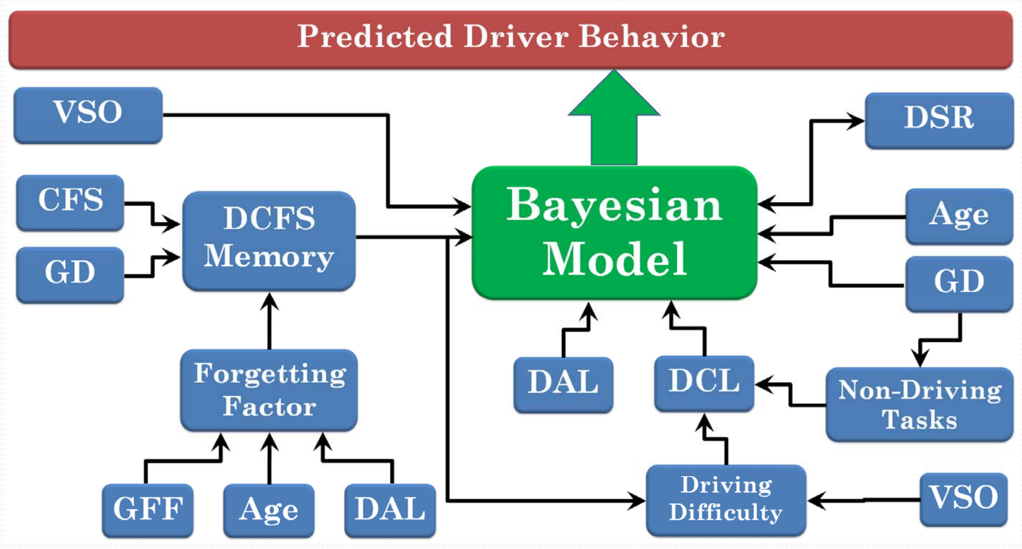
Predictive Behavioral Model

Our conjecture is that the analysis of driver gaze direction (and other facial features) fused with the knowledge of the environment surrounding the vehicle (and its odometry) lead to the possibility of predicting driving behavior for short time frames.

For this purpose, we devise a Real-Time Descriptor (RTD) for a moving vehicle essentially consisting of a CFS, a CSD, and a VSO descriptor.

The Figure on the right shows the retroactive mechanism in which both the current and predicted descriptors (CSD, CFS, and VSO) assist in determining the safety level of the context derived from the current and predicted RTD (CFS is a Context Feature Set descriptor, including lanes, vehicles, pedestrians, and signs properties, VSO is the Vehicle State and Odometry descriptor, and CSD is the Cognitive State of Driver descriptor).



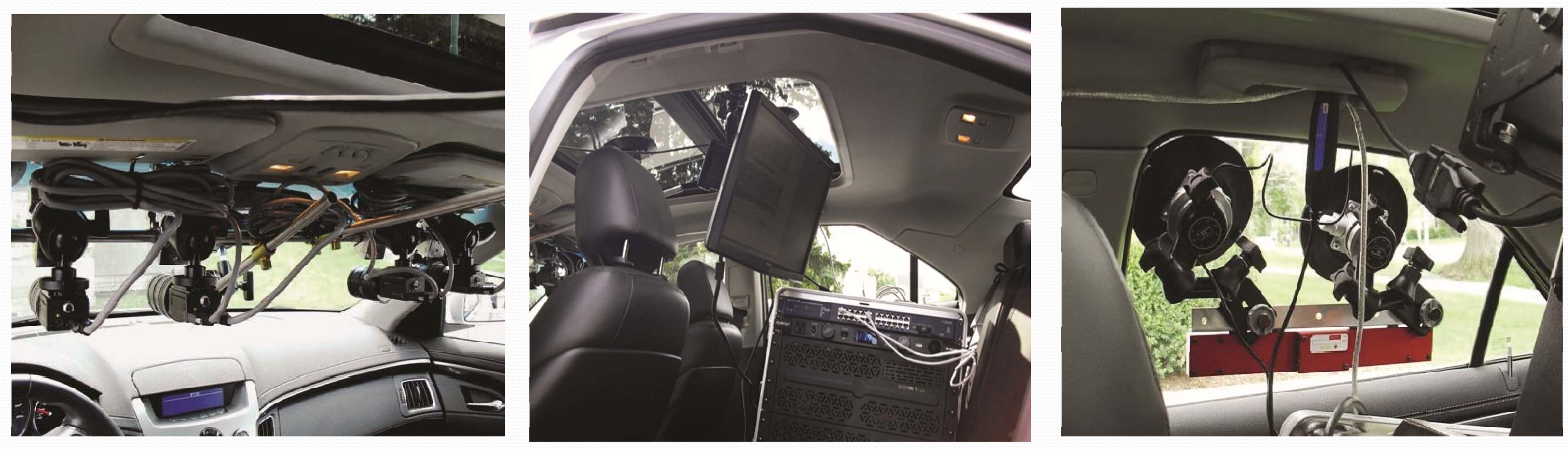


At the heart of the behavioral prediction engine is a Bayesian model which takes the current CSD, CFS, and VSO as inputs and predicts actuation behavior of the driver in the next few seconds.

It also gathers statistical information about driving decisions and errors in a Driver Statistical Record (DSR) which can be used over time to improve the prediction accuracy. The current CSD and CFS are in turn used to establish a Driver Memory of Surroundings (DMS) based on the attention level and gaze direction analysis of the driver. A General Forgetting Factor (GFF) is applied to the DMS as time elapses to reflect common characteristics of short-term visual memory. In addition, a Driver Cognitive Load factor (DCL) is inferred, based on the activities engaged by the driver, which in turn impacts the DMS, among other things.

In-Vehicle Laboratory

The design of the instrumented vehicle follows principles of sensor portability and computing scalability. Sensor portability is achieved by using vacuum devices to attach the instrumentation equipment to the interior glass surfaces of the vehicle (see Figure on the right), such as stereo camera rigs, LCD screens and GPS units without the need to perform permanent modifications to the vehicle. The odometry is obtained from the OBD-II outlet located under the dashboard on the driver's side of the vehicle.



Conclusion and Directions

We have developed a vehicle-independent, portable and scalable in-vehicle instrumentation for i-ADAS. Our motivation to develop this in-vehicle research platform stems from the observation that while injuries per driven kilometer are in decline in developed countries, a reversed trend can be observed elsewhere in the world . Technologies such as i-ADAS have the potential to significantly reduce the burden of vehicle accidents and their consequences.