Automatic Recognition and Understanding the Driving Environment for Driver Feedback (DOT Goal: Safety; Topic: Technology-Related Research)

For a smart driving system must include two key components to be able to generate recommendations and make driving decisions that are effective and accurate: 1) The environment of the car and 2) the behavior of the driver. We will investigate advanced concepts for both. Our long-term goal is to develop techniques for building internal models of the vehicle’s static environment (objects, features, terrain) and of the vehicle’s dynamic environment (people and vehicle moving in the vehicle’s environment) from sensor data, which can operate online and can be used to provide the information necessary to make recommendations, to generate alarms, or to take emergency action. Our overall approach is to combine recent progress in machine perception with the rapid advent of onboard sensors, and the availability of external data sources, such as maps.

Given input (images and 3D) from sensors, the first component of our approach illustrated in Figure 3 relies on recent development in the general area of scene understanding. Specifically, our approach is to extend state-of-the-art machine perception techniques in three areas: 1) scene understanding from images in which objects, regions, and features are identified based on image input; 2) scene understanding from the type of 3D point clouds acquired from, for example, stereo of LIDAR systems; and 3) analysis of moving objects which includes the ability to predict likely future motions in addition to modeling the current trajectory.

The second key component of our approach is to extend the machine perception techniques to incorporate a complete ensemble of constraints from this application and environments. The technical challenge is to combine data of a statistical and “continuous” nature such as sensor signals and low-level features with knowledge of a symbolic and discrete nature. In fact, our group is leading state-of-the-art research in formal methods to combine statistical and symbolic sources of data in many domains. A key development in the automotive industry is the availability of massive amounts of data from a variety of external sources. Accordingly the third component of our approach is to develop techniques to maximize the use of external sources of information. We propose to start by using current map data from navigation systems to generate priors on distribution of features and objects in the environments, and to generate priors of pedestrian and tracking activity. We will anchor the development of this part of our approach on our experience using contextual sources of information.

While using domain knowledge and contextual information from many sources is not new in machine perception, the exciting revolution afforded by the proliferation of in-car IT and communication elements makes it possible to implement this vision. Moreover, the structure of the Center provides the needed expertise in data analytics, communication, trust in data, and other issues, toward a realistic design of a perception system that is truly integrated with all the sources of information.

Desired Outcomes and Metrics

Year 1: (a) Algorithms for estimating environment representations from cameras, stereo and Lidar. (b) Detailed performance analysis on a set of typical scenarios.

Year 2: (a) Framework for incorporating domain knowledge and sources of contextual information. (b) Implementation using map data to predict prior distribution of object labels. (c) Detailed performance analysis documenting improvement afforded by the information-access components of the car.

Capabilities and Experience

Lead: Prof. Martial Hebert (CMU), This approach is supported by a strong body of prior research in understanding environments from sensor data in the areas of image and 3D sensor data interpretation. This is evidenced by publications in all of the top-tier venues in computer vision and robotics, and by awards in these communities (Best Paper Awards CVPR 2006, Runner-Up ECCV 2010,
Best Student Paper runner-up, IRA 2011). Perception techniques were integrated on autonomous ground systems. He has led projects in machine perception for ground vehicles for the past 20 years for ARL, DOE, and NASA, most recently as Perception Lead for the ARL-funded Robotics Technology Alliance, a consortium of seven institutions focused on advanced unmanned ground systems.

This research is funded in part by the U.S. Department of Transportation’s University Transportation Centers Program.