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V2Eye: Enhancement of Visual Perception from V2V Communication

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Abstract

The near future will see production vehicles equipped with intelligent Advanced Driving Systems using various sensor modalities. Meanwhile, other aspects such as Vehicle-to-Vehicle (V2V) communications have emerged as means of assisting drivers. We propose a framework (V2Eye) in which V2V augments and extends the range of visual sensors in ways that have yet to be explored.

I. INTRODUCTION

Vehicular networks have been an area of research for the past two decades [1]. Interest has been shown by researchers, government agencies, and manufacturers in developing technologies and protocols for vehicular networks. There are major areas in which unique problems must be solved, including protocols for the physical and link layer, higher layer protocols to deliver traffic, safety, and security services. Beyond these challenges, vehicles from different manufacturers must be able to communicate, rendering standardization essential.

Some standardization has already occurred with the IEEE 802.11p draft standard and allocation of 75MHz in the 5.9GHz spectrum for Dedicated Short Range Communications (DSRC) for the physical and link layer protocols. Further standardization with the IEEE 1609 draft standards for higher level protocols and services is ongoing [2].

Vehicular networking technologies can provide detailed information about other vehicles in a large area, while sensor-based technologies can provide more detailed information about the environment immediately surrounding a vehicle in real-time. Being able to combine both sources of information provides greater detail and breadth than any one technology can provide on its own. How to do this exactly is an open research problem.

A large array of sensing devices and data fusion strategies have been devised and deployed to create effective Advanced Driving Assistance Systems (ADAS) [3]. Alternatively, several functions of ADAS may be realized using V2V communication protocols. Examples include the diffusion of traffic information, [4], collision warning systems [5], lane changing assistance [6], and tracking neighboring vehicles [7]. However, the use of V2V to extend and enrich the potential of other sensors has yet to become a research topic of its own. We advocate that it should, because the type of information that can be fused is complementary by nature and extends the perceptual range of vehicles.

II. LAYERED APPROACH TO INTELLIGENT VEHICLES

The next generation of ADAS will require extensive data fusion and analysis processes, owing to ever increasing amounts of available vehicular information from sensors, V2V, and V2I (Vehicle-to-Infrastructure) communication. In this context a layered approach is best suited for real-time processing. In particular, such an approach enables bringing real-time data from sensors to a common level of compatibility and abstraction which significantly facilitates fusion and analysis processes. Our proposed computational model consists of four layers, with increasing levels of data abstraction (see Figure 1). The innermost layer consists of the hardware and software required to capture vehicle odometry, sequences from visual sensors, driver behavioral data, and V2V communication. 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 behavioural data with models of behaviour that are appropriate given current odometry and traffic conditions.

A. Vehicle Instrumentation

Contemporary vehicles equipped with On-Board Diagnostic systems (OBD-II) allow vehicle sensors to report on current status via a standardized interface through which odometry is made available in real-time. OBD-II to USB hardware interfaces with appropriate drivers are now common devices used to feed vehicle-related information to on-board computers or similar devices at frequencies generally comprised between 20 and 200Hz. Several vision systems must instrument the vehicle in order to appropriately monitor the immediate environment and the behavior of the driver. These systems must be capable of high sampling rates (30Hz or more) such that sufficient accuracy in automated vision processes is achieved. (Figure 1 shows the on-board systems of the instrumented vehicle).

Fig. 1. *The in-vehicle laboratory:* **a) (left):** *on-board computer,* **b) (center):** *front visual sensors,* **c) (right):** *side visual sensors.*

B. The V2Eye Framework

V2Eye consists of the systems, strategies, and implementation of the concept of using V2V to extend visual sensor range. The question then becomes what can be achieved by coupling V2V and sensory input? For vehicles within sensory range, information such state of odometry, presence of nearby vehicles, and driver cognitive state can be exchanged. The vehicle receiving such information obtains a timely advantage as to how to react before other vehicles effect maneuvers. Conversely, what can be gained with communicating with vehicles which are not within visual range? A very simple example involves an intersection where a corner building occludes the view. Vehicles coming the other way would not be detected with visual sensors and yet their presence could be revealed through V2V communication. While these are trivial examples, the realm of research is much larger: it is easy to realize the potential that is held by integrating V2V communication with sensory perception. While we do not address the challenges posed by V2V security, there remain numerous critical problems in the way of implementing these integrative concepts:

- Identifying the type of V2V services that should be made available to ADAS (and vice-versa) to improve safety. Not all V2V information turns out to be useful for ADAS. In this sense, experimental research using simulators will reveal the types of V2V services that are most critical for ADAS.
- Communication protocols with sufficient reliability, bandwidth, and range must be devised [1]. Numerous issues still remain with V2V communication, including addressing modes, transmission power (regulated), and real-time requirements.
- Real-time data fusing schemes between V2V and sensors which increase the general reliability of the system are required. Such issues go beyond the mapping of the vehicular environment, as reliability measures must be integrated into the fusion techniques.
- The development of effective ADAS capable of warning driving agents in a timely and reliable fashion constitute the ultimate goal of this initiative and the related research challenges are of a multidisciplinary nature.

Within their visual range, the on-board sensors provide information on driving conditions in the vicinity of the instrumented vehicle. This information comprises: relative position and speed of visible vehicles, position of instrumented vehicle with respect to road lane, and obstacle detection. Sensors monitoring the driver provide information on: driver head pose, 3D gaze direction, blink events, lip movements, and level of attention. The CANbus of the instrumented vehicle provides vehicular information such as independent wheel rotational speed, state of steering wheel, brake, accelerator pedals, and position (on-board GPS).

V2V could enhance these perceptual modalities by providing more information on visible vehicles, and reveal the presence of other vehicles outside the range of sensors. Conversely, on-board sensors can assist V2V communication by making information on non-communicating elements (other drivers, pedestrians, cyclists, and obstacles) available to nearby instrumented vehicles. Toward this end, we define a driver-centered frame of reference, in which elements of the Cognitive State of Driver (CSD) descriptor (head pose, gaze direction, blink events, lip movement, level of attention), the Contextual Feature Set (CFS) descriptor (other vehicles, road lanes, obstacles, obtained through both sensors and V2V communication), and the Vehicle State of Odometry (VSD) are transformed into (see Figure 2 for a depiction of the CSD, CFS, and VSD Real-Time Descriptors (RTDs)).

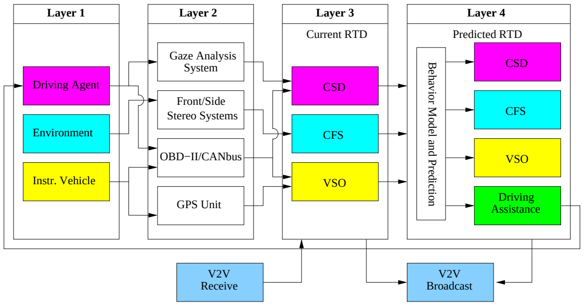

Fig. 2. *A description of vehicular current and predicted states with respect to the layered approach. The reception of V2V information enriches the elements of both the current and predicted RTDs.*

V2V communication and sensor-based ADAS can be integrated in such a way as to augment the available information on other vehicles within sensor range, detect the presence of vehicles beyond sensor range, and provide information on non-communicating elements such as pedestrians and obstacles.

III. DIRECTIONS

The complementarity of information from on-board sensors and V2V communication is expected to form the basis for new approaches in ADAS technologies. We have instrumented a vehicle with a variety of sensors, including a number of cameras. Our current focus is on establishing the framework and models for the fusion of both types of information. We are in the process of developing algorithms to enable the visual information to be shared among vehicles using V2V as an initial step in understanding the challenges of data fusion and sharing. Ultimately, the integrated information will be able to provide drivers with information beyond that offered by ADAS only.

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