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Vehicle Iconic Surround Observer: Visualization Platform for Intelligent Driver Support Applications

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Abstract— **With the introduction of intelligent driver support systems, vehicles have become more comfortable and safer. But, these systems require new sensors and the information they contain must be efficiently presented to the driver. The cognitive demands for interpreting these signals may prove to be a distraction with negative impact on driving performance. This work describes a unified visualization scheme, the Vehicle Iconic Surround Observer, capable of introducing new surround sensors into a common display environment which quickly conveys critical surround context with minimal driver interpretation.**

I. INTRODUCTION

Today's automobile is a complex moving laboratory. Numerous electrical mechanical systems perform in unison to enable a safe and enjoyable driving experience. These subsystems are equipped with essential sensors to monitor the vehicle health. But, in addition to the health sensors, there has been a trend to use increasingly more sensors in automobiles which is driven both by legislation and consumer demands for higher safety and better driving experiences [1].

Most of these supplementary sensors are internal to the vehicle operation and has little affect on typical driving. Therefore, it is unnecessary for a driver to know about their existence until one signals a problem. However, vehicles are now being equipped with sensors for intelligent driver support systems (IDSS), assistance systems for both comfort and safety applications, which are directly applicable to driving. These sensors measure the state of the external world, the vehicle, and inside the cockpit to perform necessary control actions [2]. Therefore, it is essential for a driver to be aware of what these systems are measuring. Unfortunately, drivers are being exposed to increasing information flows (not all related to the driving task) and might not always be capable of receiving and understanding these messages. A driver might be tired or distracted because attention is focused on a complex driving environment. As Amditis *et al.* [3] point out, there are several key questions to answer regarding driver notification from automotive sensing:

1) How to avoid driver overloading from disparate information flow?
2) What information should be delivered, when, and how?
3) How to avoid interference between differing information flows?
4) How to avoid the negative impact of these information flows on the driving task?

This work presents a unified visualization display to integrate various assistance technologies. The visualization seeks to maximize utility and surround awareness while minimizing the cognitive load and distraction to a driver. Instead of asking the driver to interpret the sensor data, the assistance systems interpretation is used to place iconic notifications on a top-down bird's eye view of the car and surrounding. The standardized view helps bridge the gap between what the vehicle knows about the surround with what a driver thinks it knows.

II. DRIVER SUPPORT SENSING AND SYSTEMS

In order to design an effective IDSS, it is crucial to have a careful understanding of how drivers make sense of their driving experience. In order to gain this insight, studies of driving and what information drivers rely on to make decisions and act are essential. These studies require capture of synchronized data of driving behavior and context [4]. Analysis tools are needed to extract the contextual cues and relevant signals from the numerous vehicle measurements of the vehicle and surround environment state.

The vehicle state is monitored through on board sensors that communicate along the vehicle CAN. These sensors include items such as accelerometers and wheel encoders to measure speed which indicate the dynamics of the ego-vehicle and the control inputs of a driver. The environment state is sensed through external sensors which can be either active or passive. The most common active sensor is RADAR because it is a mature technology well suited for detecting and tracking objects. On the other hand, passive technologies are desirable because they do not require any signal transmission, which can suffer from interference, to operate. Even with degraded performance under night time conditions, cameras are the most popular passive sensory modality. Cameras are an attractive automotive sensor because they can be used for multiple purposes. A single lens can be multi-tasked to perform both lane and vehicle detection for example. Wide-angle lenses as well as omni-directional imagers, which use a mirrored lens, provide a large field-of-view (FOV) on a single CCD but at lower resolution. Panomorph lenses, which can control distortion, have been proposed to provide high resolution hemispheric coverage [5]. The decrease in cost coupled with an active research

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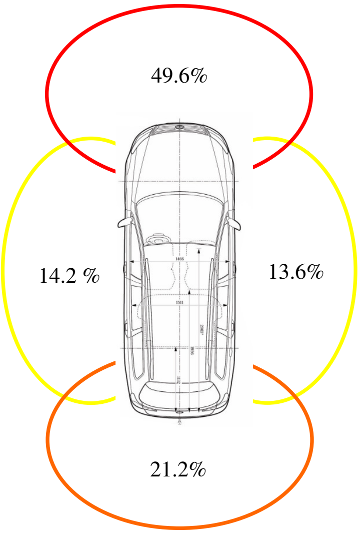


Fig. 1: Initial impact points of collision according to the 2006 Traffic Safety Facts report conducted by NHTSA. Half of all accidents occur in the surrounding regions that are not normally observed during driving (sides and rear).

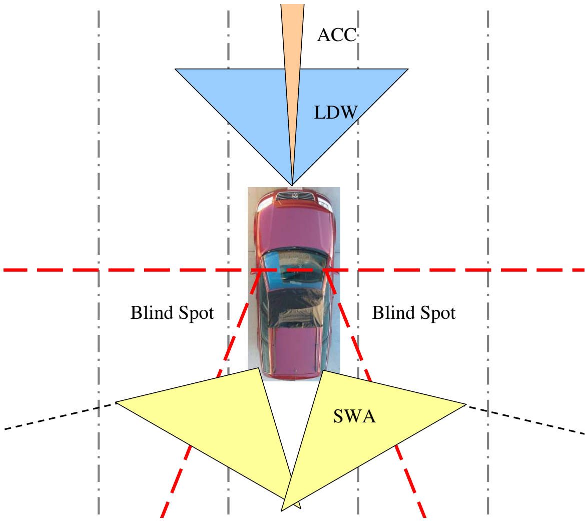


Fig. 2: Sensor configuration and coverage typically available in commercial vehicles today. The ACC system uses a narrow but long-range radar, LDW uses a camera, and SWA uses either cameras or radars. Notice the blind spot (in red) is significantly reduced with the SWA system.

community has made video a promising future automotive technology.

Surround awareness is critical for driving safety. According to the 2006 Traffic Safety Facts report conducted by the US National Highway Traffic Safety Administration, half of accidents occur in the regions least observed during driving. The diagram in Fig. 1 shows the frequency of different initial points of impact of accidents; in the front (49.6%), passenger side (13.6%), driver side (14.2%), and rear (21.2%) of vehicle. In order to mitigate the damage from these accidents, car manufacturers have begun to include sensors specifically designed to monitor these danger zones. Sensor configurations have been introduced to reduce the blind spot (shown in red in Fig. 2) along with driver support systems. An example system is automatic cruise control (ACC) which provides longitudinal control. A safe following distance behind a lead vehicle is maintained using a narrow field of view (FOV) radar (or laser). Cameras are used for lane departure warning (LDW) systems which detect lane markings on the road to recognize lateral lane positioning. This system enables warning of an inattentive driver when drifting out of their lane. The side warning assistance (SWA) system monitors the side/rear of the vehicle to warn of obstacles in the vehicle blind spots. Car manufacturers have successfully used both radar and cameras for SWA. The diagram in Fig. 2 indicates a typical sensor configuration and coverage provided in today's vehicles.

III. DRIVER NOTIFICATION/FEEDBACK MODALITIES

A major concern when developing an assistance system is the design of proper methods to interact with the driver. The results from assistance calculations need to be conveyed to a driver in a meaningful fashion in which the representation is simultaneously pleasing to a driver. In addition, a driver needs to be able to quickly understand and comprehend the connection between the IDSS calculation and alert method. If there is a disconnect between what the car is telling the driver and what the driver thinks is going on then there will be distrust in the system [6] which leads to deactivation of the service.

A. *Haptic*

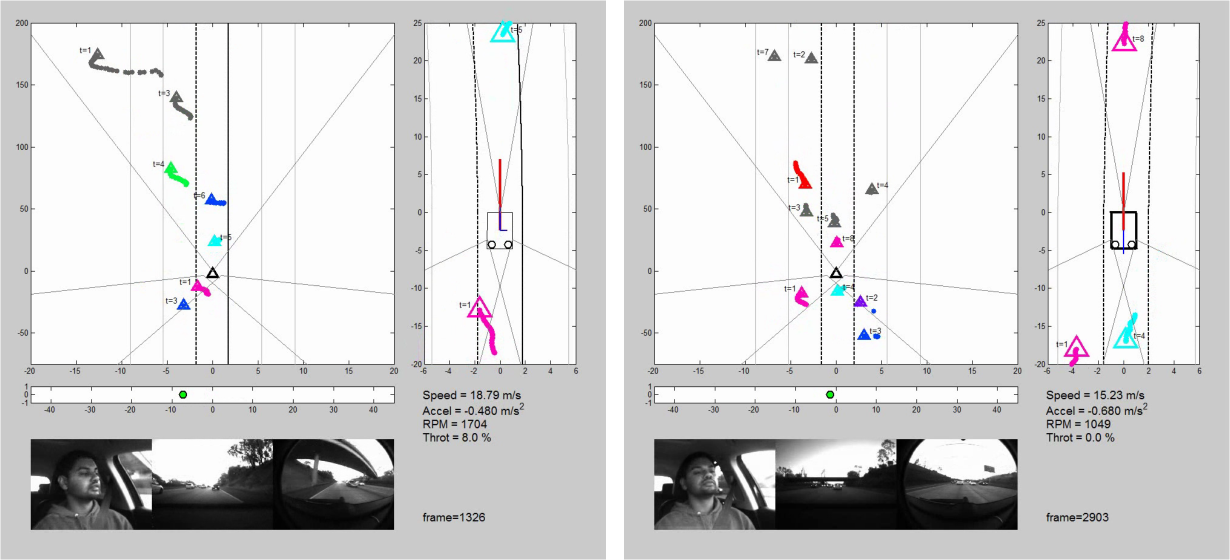
Haptic devices provide force feedback or touch sensitivity such as controlled vibrations of steering wheel, accelerator, brake, and seat. The advantages of these interfaces are that they are intuitive and can alert a driver quickly even under distraction. As noted in the work of Sharon *et al.* [7], the guidelines for tactile feedback insist that it should be given

- right after the task for comprehension and
- with an associated device with relevance to understanding (*e.g.* steering wheel vibration for steering error).

These restrictions may limit the amount of information that can be conveyed in urgent situations [8].

B. *Auditory*

Early notification systems included auditory beeps to signify something of importance. A noise is produced when a driver forgets to fasten the seat belt, turn off the headlights, or leaves the key in the ignition. The sounds need not be binary, though, as evidenced by ultrasonic sensors used during reversing for parking assist. The closer an obstacle, the louder/faster the beeping sound. But, this becomes annoying because a driver backing up may already realize the obstacles are around. In fact, auditory mitigation strategies have less acceptance than visual cues but are more effective under cognitive load [9]. Still, more time is needed in order to convey more information in the auditory channel, as done



(a) (b)

Fig. 3: Example data collected from the instrumented vehicle. Trajectories are collected from both the front and rear of the vehicle. (a) The pink rear vehicle is starting an overtake on the driver side. (b) A number of vehicles are in close proximity during the approach to congestion.

with navigation directions. The distrust for audio may stem from the disconnect between a sound and the subsystem generating the notification.

C. *Visual*

Many of today's IDSS utilize visual stimuli for notification. Visual displays are well suited for transmitting the rich information needed for automotive understanding because a human's preferred sensory modality is visual [9]. The world is absorbed through the eyes which quickly process and understand visual information.

1) Indicator Light: Indicator lights have been used as a more localized notification method. Here a light comes on in a location marked for a particular assistive system. In this way, the assistance functionality and warning are tightly coupled. An example of this technique is Volvo's blind spot system. A yellow light on the side view mirror indicates when there is an obstacle in the blind spot that would prevent safe lane change.

2) Specialized Display: The vehicle dashboard is a visual interface designed to display information such as speed on the speedometer, miles traveled on the odometer, or RPM on the tachometer. More recently, displays to present specific information needed for assistance systems have appeared inside automobiles. The presence of a lead vehicle is noted by a car icon for ACC and the lane markers indicate lane tracking for the LDW system. These devices are able to convey needed information quickly but it can be distracting to see so many meters. The limited space afforded in a vehicle encourages display methods that convey multiple signals simultaneously in limited space or for multi-function displays.

3) Video: Cameras are rapidly becoming a favorite automotive sensor because it displays the world as humans see it and can be multi-purposed for both driver feedback and analysis. Back up cameras have been installed for years to display what is directly behind the car. Large field of view (FOV) setups, such as fisheye (wide-angle) lenses and omnidirectional cameras, are well suited for monitoring vehicle surround but at the price of image distortion which affects human perception. Virtual views can be used to provide a more human-like view but these synthetic reconstructions suffer from low resolution [10].

As the price of cameras has gone down and processing power has improved, more video sensors have found a place on the vehicle. Newer assistance techniques, utilizing multiple cameras, provide a full 360° view of the car (at high resolution) rather than just a single view. All the major automotive manufacturers stitch together video from the front, rear, and sides into a surround mosaic. Unfortunately, the surround mosaic, while wide angled, provides little depth which limits safe usage to low speeds as encountered during parking. In addition, the surround video view asks a driver to process more information for surround comprehension which further limits its usefulness in critical situations.

IV. VISUALIZATION COMPONENTS

The initial design goal for the sensor visualization was to develop a discovery tool. The tool was aimed at assisting the design of advanced driver assistance systems by providing a synchronized view of sensor systems. There are five main components to the visualization system:

- surround obstacle mapping
- visual lane information

Fig. 4: Full 7 camera capture configuration: (left) 4 videos view the vehicle surroundings. (right) 3 videos observe the driver behavior by monitoring the head, hands, and feet.

(a) (b) (c)

Fig. 5: Side looking stereo camera configuration for blind spot monitoring.

- vehicle dynamics
- surround video
- driver monitoring

By integrating noteworthy measurements, the contextual and situational awareness of the surround was increased for improved safety understanding (situational understanding).

During live display, only the most relevant information is displayed to the driver. Rather than present raw video, which requires complex interpretation in real-time, only the surround obstacle map representation is used. This decreases visual clutter by utilizing an iconic representation and creates a connection between what the vehicle sees and what a driver thinks the vehicle sees.

A. *Surround Obstacle Mapping*

The surround obstacle map is generated from vehicle detections by external sensors. Typical sensors in use by manufacturers are radar (ACC, SWA), laser (ACC), and video (SWA). Stereo cameras have recently become very popular because of active research by the vision community. Specialized research vehicles utilize more exotic very high resolution sensors such as LIDAR or the Velodyne 360° scanning laser because price is not an issue. Ultrasonic sensors are used for parking assist technologies but are limited to very short range and low speeds and therefore not applicable during normal driving.

B. *Visual Lane Information*

Today's vehicles use cameras to detect the lanes of the road in order to warn a driver when drifting out of the lane (LDW) or in more aggressive manner help a driver stay within a lane through corrective steering (lane assist). Key information to be extracted from lane cameras are the width of the lane, curvature of the lane, and position within the lane.

C. *Vehicle Dynamics*

While there are many different internal vehicle sensors only a few are critical for a driver. The key measurements considered are those typically found on the normal dash display since these are the signals that a driver is most familiar with. This consists of the vehicle speed, acceleration, rotations per minute (RPM), throttle position, steering angle, and blinker state.

D. *Surround Video*

In addition to sensor measurements and system output, the visualization included raw video. Video could not be ignored during sensor discovery because of its rich semantic content. Video allows human verification of the external sensor detection results and the potential to add video based analysis. Typically, the video was used just as a verification tool and to associate contextually meaningful labels to driving situations.

E. *Driver Monitoring*

The vehicular testbeds are equipped with a camera facing the driver. The camera focuses on the face of the driver and used to understand attention and distractions. The head pose and eye gaze of a driver can be seen to estimate visual attention. Other studies such as driver fatigue or affect and emotional characterization are possible.

V. VISUALIZATION EXAMPLES

The following section presents examples of the five visualization components used for automobile data exploration. All are synchronously viewed together when developing new IDSS. Fig. 3 shows two example frames of the development tool for one of the LISA test vehicles. During this data exploration phase all components are examined to understand situational context and to describe the signals most important for the support task.

Using the knowledge from exploration, a unified visualization display was developed to integrate the outputs of various assistance systems. The display utilizes a simple iconic representation of the automobile surround to convey environmental awareness with minimal cognitive loading and distraction. The top down display is presented both on a monitor as well as an experimental head-up windshield display.

Fig. 6: 4 Camera configuration for front looking stereo.

A. *Supplementary Video*

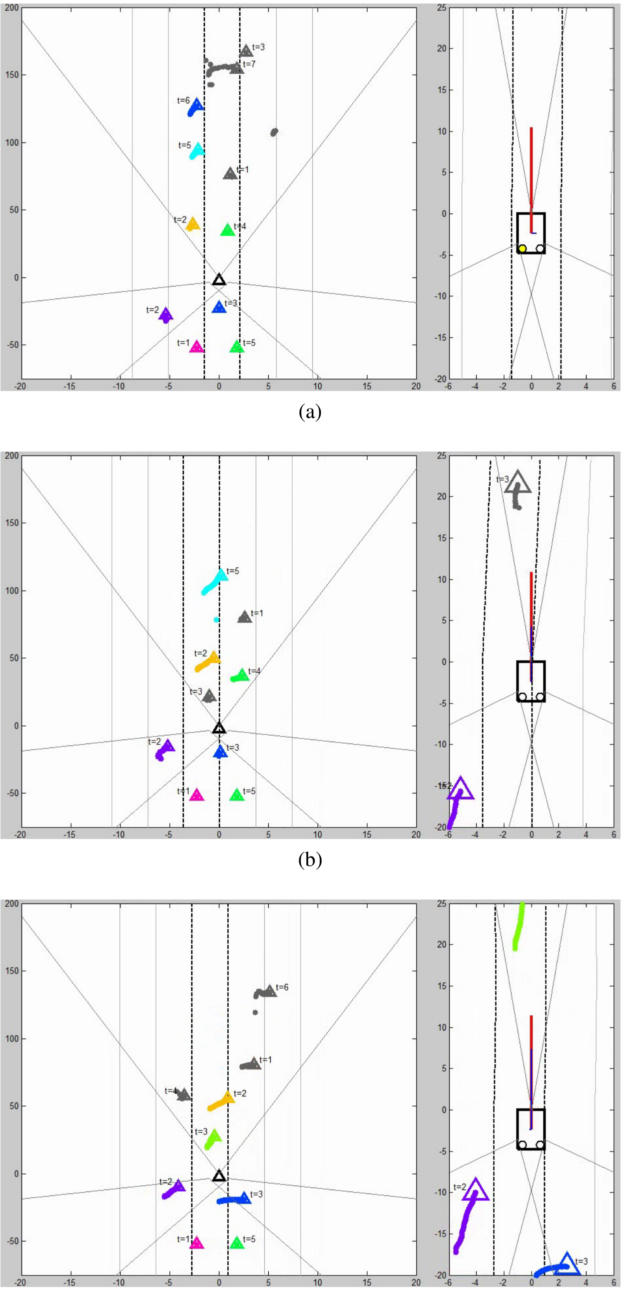
Video provides a rich information source for both driving context and for algorithm development. Fig. 4 shows 4 surround videos on the left hand side and 3 driver video streams on the right. Rectilinear cameras view through the front windshield (for lane [11] and vehicle [12] detection) and two out of the rear window while an omni-directional camera provides a full 360° view (used for surround saliency [13]). The head camera has been successfully used to help infer driver intentions [14]. Stereo camera pairs have been installed to monitor the blind spots on the side of the vehicle as seen in Fig. 5. Another configuration (Fig. 6) used two front looking cameras for wide baseline stereo which has significantly greater FOV than ACC sensors.

B. *Obstacle Map View*

The obstacle map view provides a top-down bird's-eye view of the vehicle surround (upper left pane in Fig. 3). At the center of the display, at coordinates (0,0), is an icon indicating the ego-vehicle for driver centered display. Obstacles are inserted around the vehicle in a wide field-of-view which extents laterally 25 meters on each side (ensuring at least 2 adjacent lanes on either side) and longitudinally forward 200 meters and 100 meters in the rear. In order to display the surround map, vehicles should be tracked to generate position estimates relative to the ego-vehicle. Velocity information can be obtained during tracking but the visualization does not include it. Instead, dynamics are handled by presenting consecutive tracking points. The locations recorded over last 2 seconds are displayed to show vehicle trajectories. The speed of the surround vehicles are inferred based on the length of the trajectory tail as well as the movement between display updates.

C. *Guide View*

The guide view provides the same top-down view of the surround but at higher resolution (upper right pane of Fig. 3). This view is similar to the parking assist views in use today as the field-of-view is more narrow but more detailed. The field-of-view is chosen to extent through the adjacent lanes laterally on either side of the ego-vehicle. The longitudinal view corresponds to the view depth for lane tracking both forward and similarly distanced in the rear. The speed is noted on the vehicle by a length matched bar. Similarly, the lateral and longitudinal accelerations are indicated by blue bars that increase in length for greater acceleration values. In this view it is possible to see the blinkers. Because of the closer view, the surrounding trajectories are much more detailed making it possible to resolve fine motion variations.



(a)

(b)

(c)

Fig. 7: Lane change maneuver. Notice the turn indicator before the lane change and the lane line as the change occurs.

Fig. 8: Heads up display with prototype surround vehicle display. The dynamic active display (DAD) is a laser-based wide-area heads-up windshield human interface system.

D. Vehicle Iconic Surround Observer

The Vehicle Iconic Surround Observer is an display which integrates a number of IDSS; ACC, LDW, and SWA. The display utilizes the outputs of the assistive subsystems to provide situational awareness while driving. To minimize cognitive loading, only the obstacle map and guide views are shown to a driver to highlight the most relevant obstacles [15]. An example of a lane change with the Vehicle Iconic Surround Observer is shown in Fig. 7. On the left is the Obstacle Map which provides the far field view and the right is the close up Guide View. It is possible to see the relative motion between the surround vehicles and the ego-vehicle using the Obstacle Map as well as environment density. The Guide View presents the closest, most threatening, obstacles as well as the lane curvature information.

E. Dynamic Active Display

The surround visualization can be implemented into a real-time heads up display (HUD). Using a unique laser display system utilizing the entire windshield as a display surface [8], a prototype visualization was designed. Fig. 8 shows the ego-vehicle, marked with an arrow, in the center of the windshield and surrounding vehicles as boxes. The iconic display techniques presented are necessary to ensure the laser is able to refresh in real-time because of its low resolution line drawing pattern.

VI. CONCLUDING REMARKS

This manuscript described the Vehicle Iconic Surround Observer, a display technology aimed at unifying external sensor presentation. The visualization provides a simple iconic and standardized driver-centered environment for surround awareness while minimizing cognitive load and distraction to the driver. The display integrates RADAR and camera processing into a bird's eye, top-down, view of the vehicle surround. By integrating supporting video in a synchronized manner, the system can be used to gain the insight necessary for the development of new driver support systems.

The proposed display scheme is merely a start for integrated assistance visualization. Future work with human factors is needed to evaluate the usefulness of the iconic surround map and compare competing display options to understand the impact on driving safety and distraction. Further visualization evaluation will help maximize situational awareness and utility while minimizing distraction.

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