The See-Through System: A VANET-Enabled Assistant for Overtaking Maneuvers

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Abstract—The use of wireless technology based on Vehicular Ad hoc Networks (VANETs) for information exchange can influence the drivers' behavior towards improving driving performance and reducing road accidents. This information can even be more relevant if it is presented as a video stream. In this paper we propose a system that relies on VANET and video-streaming technology: the *See-Through System* (STS). The system enhances driver's visibility and supports the driver's overtaking decision in challenging situations, such as overtaking a vision-obstructing vehicle. The use of the *See-Through System* provides the driver with an additional tool for determining if traffic conditions permit starting an overtaking maneuver thus reducing the risk of overtaking. We tested the *See-Through System* on an experimental vehicle on the road as well as in the context of a driving simulator for real world environment. Results are promising, since the use of the 802.11p standard wireless communication protocol allows a vehicle-to-vehicle connection without significant delay and the totality of the participants regarded the information provided by the STS as useful.

I. INTRODUCTION

Advanced Driver Assistance Systems (ADAS) are designed to increase the driver's awareness of the surrounding environment, resulting in enhanced safety and comfort. Examples of such systems are GPS navigation, adaptive cruise control (ACC), lane departure warning, night vision, adaptive light control, pedestrian protection, traffic sign recognition or blind spot detection. Many of these systems rely on a type of sensor which is becoming popular in modern vehicles: windshield-installed cameras. The images captured by these cameras are processed by software or dedicated hardware which is capable of identifying, for instance, the distance to the preceding vehicle, the lane markings on the pavement, pedestrians, or speed limits posted on traffic signs. The advent of Vehicular Ad Hoc Networks (VANETs), which are enabling infrastructure-less vehicle-to-vehicle (V2V) communication, open the possibility of designing ADAS which base their functioning in data collected from sensors residing in *other* vehicles. VANETs are thus enabling the design of cooperative advanced driver assistance systems (co-ADAS). Increasing the awareness of a driver through visual data remotely collected from the windshield-installed camera sensors of nearby vehicles is a promising avenue for the design

of co-ADAS. For instance, a recently published work has shown that the combination of images from several cameras allows drivers to see through opaque areas, thus increasing the driver's visual perception [1].

The overtaking of long and vision-obstructing vehicles on the road, such as trucks, is a difficult and challenging task when there is no overtaking lane other than the one used by vehicles traveling in the opposite direction. Vision-obstructing vehicles, where the absence of transparent surfaces disables seeing through the vehicle, clearly reduce the awareness of drivers that travel behind such vehicles. As a result, a longer following distance is normally kept by the vehicle traveling behind, to improve the field of vision, as well as to increase the reaction time in the event of a sudden brake or maneuver by the vehicle in front. In addition to this distance, the length of vision-obstructing vehicles is typically large. For example, the maximum overall length of a truck in the majority of the EU and EEA member states is 18.75 meters. In some countries like Sweden and Finland this length can even reach 25.25 meters. In other areas of the world like Argentina, Australia, Mexico, the United States and Canada even larger vehicles exist, called road trains that are used to move extremely large loads like several trailers. The maximal length of the largest road trains, which are the Triple and AB-Quad road trains can reach 53.5 meters.

Overtaking such vehicles through the use of the opposite direction traffic lane is thus a challenging task, and all the information that can support the decision of the driver in starting this maneuver is very useful. Drivers of such large and vision-obstructing vehicles are aware of such difficulty and we often observe their cooperation through hand-waving or actuation of turn signals to inform the driver behind that it is safe to overtake. VANETs allow replacing this unreliable driver-to-driver communication by automated vehicle-to-vehicle communication carried out through wireless technologies such as the Dedicated Short Range Communication (DSRC) protocol [2], supporting a co-ADAS for the overtaking maneuver that leverages the dissemination of windshield-installed cameras in modern vehicles.

In this paper, we propose the *See-Through System* (STS), a co-ADAS for the overtaking maneuver of long and vision-obstructing vehicles that uses VANET technology to provide a video-streaming between the vehicle in front and the vehicle behind. The STS allows the overtaking vehicle to have the visual perspective of the road of the preceding vehicle, enhancing the driver's visual perception of vehicles traveling in the opposite direction lane.

We implemented and evaluated the system using DSRC

radios installed in vehicles and driven in real road scenarios. In addition, we also implemented a realistic driving simulator where the usability of the system is further evaluated.

The remainder of this paper is organized as follows. In the next section we revise related work in the areas of VANET-based video streaming and driver assistance systems for the overtaking maneuver. Section III presents a detailed description of the STS system and Section IV reports on the evaluation of the system, both using road-based experiments and a driving simulation environment. Finally, Section V concludes the paper.

II. RELATED WORK

A high amount of research has been dedicated to the development of innovative driver assistance systems [3]. For example, some radar-based approaches intend to lower road accident risk despite low visibility, identifying road vehicles and obstacles [4], [5]. Different crash avoidance systems focus on forward collision warning, intersection, blind-spot, lane change applications and other safety warning systems that rely on wireless technology. These systems consist of sensors that provide the vehicle with 360 degree awareness [3], [6]. Direct wireless communication is also used for vehicles to share information in vehicular ad-hoc networks thus transmitting information from one vehicle to surrounding vehicles [7], [8], [9]. An example of applicability of information transmission through VANET was shown in [10], where a protocol for locating a car with vision sensors was proposed. Most technological approaches use a large spectrum of sensor information and combine several methods for object or pedestrian detection and the classification in object types [11], [12]. In addition systems based on artificial vision have been suggested to summarize information about vehicle's environment such as road, traffic, and traffic signs [13]. Also the role of image-based Advanced Driver Assistance Systems (ADAS) for different applications using built-in cameras to assist the driver was studied with different approaches [14], [15]. The use of wireless technology based on VANETs for information exchange to reduce road accidents is especially promising in this context; especially if this information is presented as a video image. VANET based video streaming technology research has been conducted in recent works. [16] proposed an architecture for video streaming to vehicle-to-vehicle (V2V) communication with multiple receivers able to handle connection problems in the V2V network related to vehicle's radio range and connection lifetime, both typical issues of the dynamic condition of vehicles [17], [18]. Following with problems related to the transmission of data associated to vehicular networks, [19] presented a distribution of visual information based on network coding that can solve potential packets corruption or loss, thus allowing a faster transmission of video files. In [1] the authors presented a system that allows drivers to see objects in motion through opaque buildings and road intersections with low visibility. The authors present a prototype based on augmented reality and the combination of images captured by several cameras that provide a driver's view and a view of what is behind the opaque surface. An effect of transparency is achieved combining the layers of both images.

The balance of accidents related to overtaking maneuvers represent between 10 and 15 % of the total percentage of road accidents [20], [21], [22]. Different studies have shown that, generally speaking, it is a challenge for drivers to estimate the time required to complete the overtaking maneuver until the oncoming vehicle arrives. This could be due to an inaccurate visibility of the road [23] or difficulties in interpreting the distance to the oncoming traffic [24]. The automobile industry has developed some overtaking assistants based on warning signals that inform the driver about the danger of starting an overtaking maneuver due to factors like existence of curves, inclination of the road or bad visibility, for example accessing the data stored in maps from navigations systems for calculating vehicle's positions and accessing information related to the vehicle motion and road architecture [25], [10]. Other systems give feedback based on data collected from monitoring the driver before and during overtaking [26]. However there is few research concerning calculations related to the distance to the oncoming vehicle [27]. Wireless technology based on VANETs can provide the driver with additional tools to solve this problem. In our approach we use VANET technology to provide the driver with the visual perspective of the road of the vehicle in its front thus enhancing driver's traffic visibility. In the next section we describe the STS system architecture.

III. SYSTEM ARCHITECTURE

The STS system is based on the following assumptions:

- Equipped vehicles have windshield-installed cameras, connected to an on-board computer that is able to compress video, recognize traffic signs and support the inter-vehicle communication protocols;
- Equipped vehicles have GPS;
- Equipped vehicles have DSRC radios;
- Equipped vision-obstructing/long vehicles display a rear sign mentioning "STS Enabled" (a VANET enhancement over the typical "Long Vehicle" sign);
- Equipped overtaking vehicles have a screen on the dashboard where the video streaming can be visualized.

Figure 2 provides a snapshot of a possible road situation where STS is being used. The functioning of the system is relatively simple. In suitable roads (one lane per direction) the traffic sign recognition software installed in equipped vehicles is able to detect if the overtaking maneuver is permitted by law. If some traffic sign does not allow overtaking, the activation of the STS will be automatically disabled. The "STS Enabled" rear sign is used to inform the overtaking drivers that the vehicle in front of them is equipped with the cooperative system. Hence, drivers closely approach the rear of the vehicle to enable STS by pressing some context-aware button on the steering wheel. Since the overtaking vehicle also detects the "STS Enabled" sign, the context for the button is automatically set by sign recognition. Upon

the activation of the system, the overtaking vehicle sends a Geocast message to a zone of relevance (ZOR) determined through its current GPS position, direction vector and speed, asking for STS cooperation. The vehicle in front receives this message and validates its participation in the STS request based on its own current GPS position, direction vector and speed. Upon validation of its participation in the STS protocol, the vehicle in front starts a geo-unicast video streaming to the ZOR of the overtaking vehicle of the signal collected by its windshield-installed camera. The overtaking vehicle receives this video streaming and displays it to the driver through the dashboard screen. The overtaking vehicle sends a message to end the protocol when the overtaking is completed, which is automatically detected by its GPS position and the ZOR of the video-streaming. An important aspect of the STS as an overtaking assistance system is that it just provides additional visibility, leaving the decision to engage in the maneuver to the driver of the vehicle. In terms of its function, the system is very similar to the rear-view mirrors that equip vehicles and that are also checked by drivers before engaging an overtaking maneuver. As happens with such rear-view mirrors, STS also suffers from blind-spots. Between the moment when opposite direction vehicles leave the area of sight of the camera of the vehicle that is streaming the video and the moment such vehicles enter the area of sight of the driver receiving the video, it is not possible to perceive them. It may seem that this blind-spot is very large, given the typical length of STS equipped vehicles, resulting in a dangerous assistance system. This is, however, a false perception, and the duration of such blind-spots is comparable to that of rear-view mirrors. If we assume that the blind-spot of a rear-view mirror is about 2 meters and that an overtaking vehicle is traveling at a speed 10 km/h higher than the vehicle being overtaken, then the rear-view blind-spot duration on the overtaken vehicle lasts 0.72 seconds. In STS, if we assume that the blind-spot of the overtaking vehicle is about 30m and that the vehicle being overtaken, as well as the vehicle in the opposite direction lane, are traveling at 80 km/h, then the blind-spot of the overtaking vehicle lasts 0.68 seconds. Nevertheless, this time can be significant and the design of blind-spot warning systems could also complement the functioning of STS.

A. Implementation of STS on the Car-2-X Protocol Stack

The implementation of STS is based on the current state of the art and evolving standards for automotive communication. Following the specifications and technologies proposed by the European Car-2-Car Consortium [28], STS is an application unit (AU) that uses the vehicle's on-board unit (OBU) to communicate in the ad-hoc network. Figure 1 describes the protocol architecture of an OBU. Basically, it is composed by different communication mechanisms for safety and non-safety applications. Infotainment applications may use the conventional IPv4 and IPv6 protocol stack, encapsulating IP packets into Geocast packets and tunneling over the ad-hoc network. Common to other safety applications, STS relies on the Geocast features to provide communication among OBUs

over IEEE 802.11p radio. Geocast is a routing protocol that provides single or multi-hop communication over the ad-hoc network and implements geographical forwarding that can address a node by its geographical position or multiple nodes in a geographical region. Geocast also implements topological-scoped broadcast to forward data packets from a source to all nodes located at a distance of n-hops. Using 1-hop broadcast, vehicles periodically broadcast small data packets, known as beacons or heartbeats, to inform other vehicles in their communication range about their ID, current geographical position, speed and heading. Each vehicle also maintains a location table containing this information of every known vehicle, and such information is updated upon the reception of new heartbeats. Thus, in STS every vehicle is aware of the other vehicles presence in the surrounding environment.
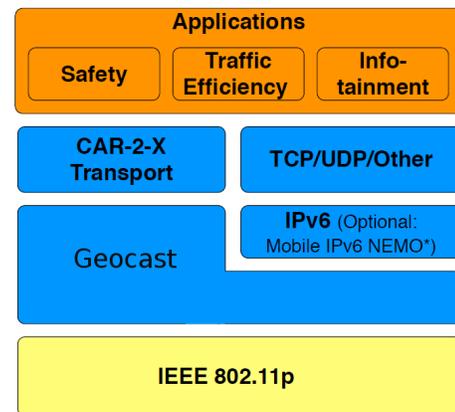

Fig. 1. Car-2-X Protocol stack

For safety reasons, an overtaking maneuver only makes sense when the vehicle in front is near and fully in the line-of-sight of the vehicle that intends to overtake. Thus, the involved vehicles must have direct communication; otherwise the AU of the vehicle that intends to overtake should not allow the activation of STS. If any kind of connectivity problem arises (i.e. network latency of video streaming) due to other vehicular safety messaging applications then the STS is deactivated automatically. Due to these natural conditions for overtaking maneuvers, STS only requires 1-hop communication, avoiding the overload of forwarding algorithms used in multi-hop communications. Thus, upon the acceptance of STS cooperation, the vehicle in front initiates a video streaming session using single-hop broadcast. Once the wireless medium is shared, every vehicle within the communication range of the server will receive the streaming packets, but only the vehicle that is interested in the STS cooperation will accept them.

B. Vehicle-to-Vehicle Video Streaming

To be feasible, our system requires a very low delay in the video streaming transmission. Since STS is only enabled when the involved vehicles have direct communication, applying video streaming between them does not face the

challenges of a persistently partitioned network, and thus, complex architectures like the one described in [16] are not necessary for the STS requirements. Since the system has been in particular conceived for situations where the vision field of the driver is reduced by an obstructing vehicle ahead and this applies in particular in a two line road and not in a highway, a scenario with more than one or two cars activating the application at the same time does not apply. In order to enable video streaming over the Geocast network layer, a transport layer protocol is required. We chose the User Datagram Protocol (UDP), which is a connectionless and unreliable protocol, but requires considerably less processing at the transmitting and receiving nodes. Reliability may be enhanced at the application layer, while Real Time Protocol (RTP) guarantees the timeliness of the data. Like a typical client-server application for the media transmission, the server side is responsible to stream its perspective of the road, and the client simply decodes and shows the stream that is being forwarded to it. The server extracts raw video data from the camera using the video4linux library. Before being transmitted, such data is encoded in order to deal with delay and bandwidth constraints of the wireless medium. To encode the stream we initially used standard video codecs like MPEG-1 and similar technologies. However these approaches save the transmitted data in a buffer to correct possible errors in the speed transmission, thus entailing problems related to delay on coding/decoding the stream, that lead to unacceptable streaming delays (more than 1 second). To assure a real-time video streaming, we use Smoke Video codec [29] that does not introduce any kind of delay regarding error correction/buffering. The same codec is also used to decode and show the stream that is being forwarded to the client.

Fig. 2. Road scenario showing the use of the STS

IV. STS EVALUATION

In this section we discuss our preliminary field test results and in the simulator context.

A. Evaluation on the road

In VANET the node mobility is provided by the vehicles themselves. The nodes are both receivers and senders of messages through the wireless network and they can communicate with other vehicles as well as with roadside infrastructure. For connectivity purposes an OBU needs to be placed inside the vehicle. For our testing platform we establish a V2V wireless connection with a range of at least 300 meters. For this purpose the OBU uses DSRC/802.11p technology. The 802.11p standard defines enhancements to 802.11 required to support wireless local area networks (WLANs) in a vehicular environment. The DSRC/802.11p operates in the frequency band 5.9 GHz, unlike the old DSRC systems that were designed for electronic toll collection and operated at 915 MHz band. The testing platform is constituted by the following elements.

- 2 LinkBirds MX V3 from NEC Electronics that provide DSRC connectivity;
- 4 High gain antennas Mobile Mark ECOM6-5500 (5-6dBi) mounted on the vehicle roof;
- Enhanced wireless drivers for establishing connectivity between vehicles;
- 1 Logitech Webcam located on the windshield.

We measure the system performance over the transmission process; in particular we focus on delay and packet loss as function of the distance.

A log file stores information automatically related to the data transmission. Note that for open loop measurements the clock reference must be synchronized, unless in the presence of an external GPS clock reference such as in this case. Results show that the system assures a long-range connection with very limited delay and a low packet loss. Given that the transmission path delay at 300 m is around $1\mu s$, the only measurable delay is the system latency. Fig. 3 shows that delay has no correlation to distance and it has a very high probability of being close to $0.1s$.
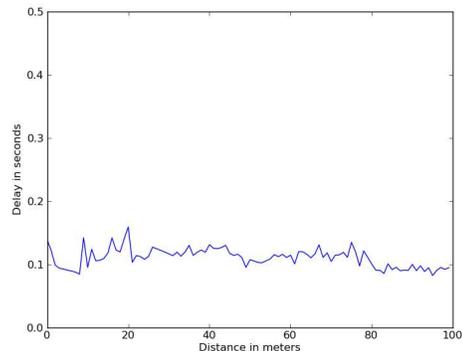

Fig. 3. Delay measurements with the DSRC testing platform

Fig. 4 shows that packet loss is very low and it is not affected by distance within the testing scenario limits. A mean packet loss close to 0.12% is perfectly negligible for wireless systems. Moreover, the bit resilience of streaming

codecs can easily compensate this small packet loss. Note that preliminary tests showed that obtaining a real-time video streaming could be performed on the top of UDP with the Smoke Video codec. This codec is especially suitable for real-time streaming since it does not introduce any kind of delay regarding error correction/buffering.
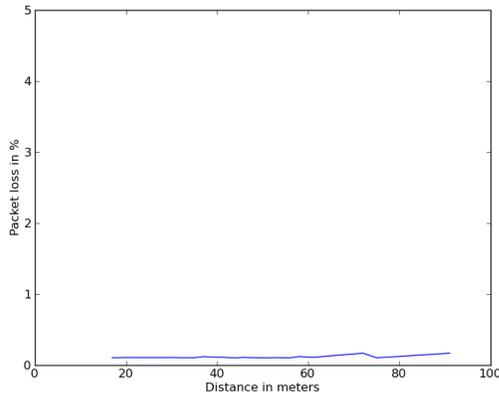

Fig. 4.   Packet loss measurements with the DSRC testing platform

B. Simulation-based usability evaluation

Fig. 5.   *See-Through System* evaluation in the context of a driving simulator

The road-based evaluation reported in the previous section provides evidence of the technical feasibility of vehicle-to-vehicle video streaming, using DSRC, in order to provide assistance for drivers in overtaking maneuvers. In addition to this technical feasibility we also evaluated the usability of STS as an overtaking assistant from the point of view of the driver. Because of safety considerations related to the use of an experimental system in a critical driving maneuver such as the overtaking of vehicles in one-road-per-direction scenarios, we developed a realistic cockpit-centric driving simulator to conduct the usability evaluation. Using the OpenSceneGraph library [30], we constructed a driving simulator on a 3D scenario of a simple road in a countryside area, with one lane per traffic direction. As

mentioned above, the STS is designed to help in the cognitive process of overtaking vision-obstructing vehicles through the use of the opposite direction traffic lane. OpenSceneGraph provides all the support for different visual perspectives of the scenario, in particular from the point of view of the cockpit of a moving vehicle. Using the OpenSceneGraph library it is simple to define the placement and angle of view of different cameras capturing the scenario and getting their respective visual scope. For STS simulation we setup two cameras: one capturing the perspective of the vehicle being driven by a participant in the STS usability evaluation; and the other with the visual perspective of the vehicle in front that cooperates with the request of STS. Figure 5 shows the physical setup of this driving simulator, with the visual perspectives of these two cameras. The large monitor projects the perspective of the first camera, while the smaller monitor mimics a dashboard monitor and projects the STS video streaming from the vehicle being overtaken. A steering wheel and a pair of acceleration and braking pedals complement the realism of the driving simulator.

We use the DIVERT traffic simulator [31] to populate the road scenario with vehicles and to move such vehicles in a realistic fashion. Vehicles include motorbikes, cars and trucks of different sizes. The 3D road scenario also displays traffic signs, such as speed limits and permission/prohibition of overtaking vehicles. To test the usability of the system through this simulator we resorted to 20 drivers recruited at the Faculty of Sciences of the University of Porto covering a range of ages between 20 and 65. Every person runs the tests six times to reach a certain training effect and to be familiarized with the simulator and the *See-Through System*. Half of the runs are performed using the STS and half of them without using it. The experiment consists on driving the given road scenario and trying to arrive as soon as possible at the destination, respecting all the traffic regulations. Trucks are programmed to drive slowly so that overtaking is enforced. We measure the time that a test person needs to drive from the starting point to the destination point, with and without STS. Before starting the experiment an overview of the system was provided to the participants. After the task, the participant completes a post-task questionnaire that addresses questions related to the usefulness of the system. The time it takes to reach the destination determines the participant's driving performance.

The experiment showed that a certain experience with test driving in simulators is required to reach the minimal required performance. Our results show a significant decrease of time to the destination with the *See-Through System* compared to not having it (See Figure 6). In addition 90.48% of the participants considers that the *See-Through System* makes it easier to overtake other vehicles and the totality of them regarded the information provided by the STS as useful. The results concluded that the use of *See-Through System* correlates with the time to reach the destination. Thus the use of the *See-Through System* provides the driver with an additional tool for determining if traffic conditions permit starting an overtaking maneuver.
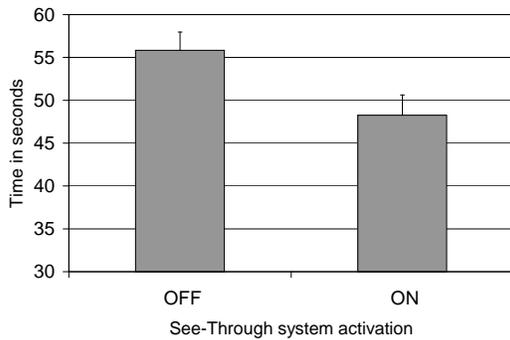
Fig. 6. See-Through System mean efficiency gains (p=0.0192; df=1; sum sq.=1077.307; mean sq.=1077.31, F 74,1=5.7359)

V. CONCLUSION AND FUTURE WORK

Several approaches to solve the problem of vehicle-to-vehicle communication have been proposed in the last years. A trend in the automotive industry is to use the 802.11p standard, a wireless communication protocol for automotive applications. Tests on the *See-Through System* related to the communication channel behavior using different related technologies confirmed the trend, since this approach allows a long-range connection without significant delay. Research in a simulation scenario showed that the *See-Through System* facilitates overtaking. This does not mean that more overtaking maneuvers are taking place when using the system, but that overtaking decisions are taken more quickly thus resulting in a better time until destination arrival. Since the functionality of the system is similar to the rear-view mirrors, that are used before starting an overtaking maneuver, and the system can be easily activated when needed, the STS is very intuitive and not distracting at all. Although the results are promising and the STS seems to be useful to the drivers, some future research regarding the design of blind-spot warning systems could complement its functionality.

REFERENCES

[1] P. Barnum, Y. Sheikh, A. Datta, and T. Kanade, "Dynamic seethroughs: Synthesizing hidden views of moving objects," in *Proceedings of the 2009 8th IEEE International Symposium on Mixed and Augmented Reality*. IEEE Computer Society, 2009, pp. 111–114.

[2] S. Biswas, R. Tatchikou, and F. Dion, "Vehicle-to-vehicle wireless communication protocols for enhancing highway traffic safety," *IEEE Communications Magazine*, vol. 44, no. 1, pp. 74–82, 2006.

[3] J. Misener, R. Sengupta, and H. Krishnan, "Cooperative collision warning: Enabling crash avoidance with wireless technology," in *Proc. 12th World Congress on ITS*, 2005.

[4] F. Küçükay and J. Bergholz, "Driver assistant systems," in *Int. Conf. on Automotive Technologies. Istanbul, Turkey*, 2004.

[5] J. Khan, S. Niar, A. Menhaj, Y. Elhillali, and J. Dekeyser, "An MPSoC architecture for the Multiple Target Tracking application in driver assistant system," in *19th IEEE International Conference ASAP08*, 2008, pp. 2–4.

[6] M. Lu, K. Wevers, and R. Van Der Heijden, "Technical feasibility of advanced driver assistance systems (ADAS) for road traffic safety," *Transportation Planning and Technology*, vol. 28, no. 3, pp. 167–187, 2005.

[7] J. Yin, T. ElBatt, G. Yeung, B. Ryu, S. Habermas, H. Krishnan, and T. Talty, "Performance evaluation of safety applications over DSRC vehicular ad hoc networks," in *Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks*. ACM New York, NY, USA, 2004, pp. 1–9.

[8] L. Chisalita and N. Shahmehri, "A peer-to-peer approach to vehicular communication for the support of traffic safety applications," in *The IEEE 5th International Conference on Intelligent Transportation Systems, 2002. Proceedings*, 2002, pp. 336–341.

[9] B. Defude, T. Delot, S. Ilarri, J.-L. Zechinelli, and N. Cenerario, "Data aggregation in vanets: the vespa approach," in *Mobiquitous '08: Proceedings of the 5th Annual International Conference on Mobile and Ubiquitous Systems*. ICST, Brussels, Belgium, Belgium: ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2008, pp. 1–6.

[10] M. Ferreira, H. Conceição, R. Fernandes, and R. Reis, "Locating Cars through a Vision Enabled VANET," in *Intelligent Vehicles Symposium*. IEEE, 2009.

[11] U. Handmann, T. Kalinke, C. Tzomakas, M. Werner, and W. von Seelen, "Computer vision for driver assistance systems," in *Proceedings of SPIE*, vol. 3364, 1998, pp. 136–147.

[12] C. Hilario, J. Collado, J. Armingol, and A. De la Escalera, "Pedestrian detection for intelligent vehicles based on active contour models and stereo vision," *Lecture Notes in Computer Science*, vol. 3643, p. 537, 2005.

[13] M. Bertozzi, A. Broggi, M. Cellario, A. Fascioli, P. Lombardi, and M. Porta, "Artificial vision in road vehicles," *Proceedings of the IEEE*, vol. 90, no. 7, pp. 1258–1271, 2002.

[14] U. Handmann, T. Kalinke, C. Tzomakas, M. Werner, and W. Seelen, "An image processing system for driver assistance," *Image and Vision Computing*, vol. 18, no. 5, pp. 367–376, 2000.

[15] N. Kaempchen and K. Dietmayer, "Fusion of laserscanner and video for advanced driver assistance systems," in *Proc. Intelligent Transportation Systems*, 2004.

[16] M. Guo, M. Ammar, and E. Zegura, "V3: A vehicle-to-vehicle live video streaming architecture," *Pervasive and Mobile Computing*, vol. 1, no. 4, pp. 404–424, 2005.

[17] Z. Da Chen, H. Kung, and D. Vlah, "Ad hoc relay wireless networks over moving vehicles on highways," in *Proceedings of the 2nd ACM international symposium on Mobile ad hoc networking & computing*. ACM New York, NY, USA, 2001, pp. 247–250.

[18] C. de Morais Cordeiro, H. Gossain, and D. Agrawal, "Multicast over wireless mobile ad hoc networks: present and future directions," *IEEE network*, vol. 17, no. 1, pp. 52–59, 2003.

[19] J. Park, U. Lee, S. Oh, M. Gerla, and D. Lun, "Emergency related video streaming in VANET using network coding," in *Proceedings of the 3rd international workshop on Vehicular ad hoc networks*. ACM, 2006, p. 103.

[20] D. Clarke, P. Ward, and J. Jones, "Overtaking road-accidents: differences in manoeuvre as a function of driver age." *Accident; analysis and prevention*, vol. 30, no. 4, p. 455, 1998.

[21] Clarke, DD and Ward, PJ and Jones, J., "Processes and countermeasures in overtaking road accidents," *Ergonomics*, vol. 42, no. 6, pp. 846–867, 1999.

[22] G. Jeffcoat, N. Skelton, and R. Smeed, "Analysis of national statistics of overtaking accidents," *Int. Driver Behaviour Research Association Report of the University of London*, 1973.

[23] R. Gray, "The use and misuse of visual information for go/nogo decisions in driving," *contemporary issues in traffic research and road user safety. Nova Science*, 2004.

[24] J. Groeger, *Understanding driving: Applying cognitive psychology to a complex everyday task*. Routledge, 2000.

[25] R. Toledo-Moreo, J. Santa, and M. Zamora-Izquierdo, "A Cooperative Overtaking Assistance System," *Planning, Perception and Navigation for Intelligent Vehicles (PPNIV)*, p. 50.

[26] S. Lee, E. Olsen, and W. Wierwille, "A comprehensive examination of naturalistic lane-changes," *DOT HS*, vol. 809, p. 702, 2004.

[27] G. Hegeman, K. Brookhuis, S. Hoogendoorn *et al.*, "Opportunities of advanced driver assistance systems towards overtaking," *EJTIR*, vol. 5, no. 4, pp. 281–296, 2005.

[28] "Car 2 car communication consortium manifesto. version 1.1." 2007, http://www.car-2-car.org.

[29] "GStreamer Documentation," 2009, http://gstreamer.freedesktop.org.

[30] "Openscenegraph," 2007, http://www.openscenegraph.org/projects/osg.

[31] H. Conceição, L. Damas, M. Ferreira, and J. Barros, "Large-scale simulation of V2V environments," in *Proceedings of the 2008 ACM symposium on Applied computing*. ACM New York, NY, USA, 2008, pp. 28–33.