Using an Intelligent Vision System for Obstacle Detection in Winter Condition

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Abstract: This paper explores the performance of an Advanced Driving Assistance System (ADAS) during navigation in urban traffic and a winter condition. The selected ADAS technology, Mobileye, has been integrated into a hydrogen electric vehicle. A set of three cameras (visible spectrum) has also been installed to give a surrounding view of the test vehicle. The tests were carried out during the dusk as well as in the night in winter condition. Using Matlab, the messages provided by Mobileye system have been analyzed. More than 2800 samples (short sequences of 5s Mobileye messages) have been processed and compared with the corresponding video samples recorded by the three cameras. In average, the selected ADAS device was able to provide 99% of true positive vehicle detection and classification, even in poor ambient lighting condition in winter. However, 72% of samples involving a pedestrian was correctly classified.

1 INTRODUCTION

The number of vehicles on the road is continuously growing, and despite the primary safety design of cars, the number of collisions and incidents is also growing (Lyu et al., 2018). The World Health Organization recently reported that more than one million persons die every year because of road accidents (Curiel-Ramirez et al., 2018).

Traditionally, the car manufacturers provide secondary safety features that can reduce a crash impact on passengers. One such feature is the airbags technology. However, with the recent progress on the vehicle mechatronics, onboard sensors and soft computing, the primary safety features are among the manufacture safety priority. These features have the potential to directly mitigate the likelihood of an imminent crash: adaptive cruise control, electronic stability, etc. (Thompson et al., 2018).

Although the deployment of these primary safety features, most accidents on the road are due to the human driver distraction (Larkin, 2006; Excell, 2005; Wright, 2016; Barclay, 2012; Chang et al., 2009). The Advanced Driving Assistance System has emerged as one of the promising technologies that has a great potential to help the driver to avoid accidents and incidents during distraction periods. Therefore, this paper focuses on the aftermarket ADAS device (Mobileye 5 series) which is based on a monocular camera for collision avoidance and mitigation.

Several studies have recently been published which, in general, highlighted the collision-reduction potential of the ADAS system. Hence, in (Chang et al., 2010), a vision system combined with a GPS sensing has been used to enhance obstacles detection and mitigate collision occurrences. This system has been shown to be effective in normal operating condition conditions (daytime, no winter condition, etc.). A similar operating condition has been reported in (Curiel-Ramirez et al., 2018; Chen et al., 2017; Excell, 2005; Fireman, 2017). In a field test, an ADAS system has shown to improve the driver alert level and reduce the likelihood of forward collision (Thompson et al., 2018). The tests have been performed on a fleet of government vehicles, and the details driving conditions are not specified. Another trial that involves an ADAS system has been performed in China (urban and highway navigation). All the tests were done during the daytime from 8:00 am to 17:30 pm. Although the outcome of the study indicated that the selected ADAS improved the drivers' longitudinal behaviors and significantly reduced the likelihood of a forward collision, no winter condition has been used as a navigation condition. Besides, the previously mentioned

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study included most of the reported results on the effectiveness and acceptance of ADAS. In (Birrell et al., 2014), an ADAS system has been tested in a real-world condition to assess if any measurable beneficial changes can be observed in the driving performance. The test scenarios include different road and traffic types. The presented results suggested that a smart driving assistance system can significantly improve the driver behavior and can lead to a fuel-saving too. All these tests have been carried out in normal weather operating condition (no winter conditions). A similar result has also been reported in (Reagan, 2019; Lee et al., 2018).

Regarding the specific problem of detecting a pedestrian, several studies have been carried out, and most of them have been performed in regular daytime without winter operating condition. These studies were done on the different type of road including urban and highway roads. Hence, in (Ke et al., 2017), a new framework has been introduced that can effectively detect in real-time a vehicle-pedestrian near through a single monocular camera. The presented results have been performed without considering winter operating conditions. Chen and al. (Chen et al., 2017) has studied the interaction of pedestrian and a vehicle at unsignalized crossings and there were able, through more than 2900 crossing events analysis, to build a stochastic interaction model based on a multivariate Gaussian mixture method. Here again, most of the analyzed events did not include winter operating conditions.

One of the most used ADAS devices in the above-mentioned studies is Mobeleye intelligent monocular vision system (Abelson, 2012; Wright, 2016; Wang et al., 2017; Vasic et al., 2016; Markwalter, 2017). Also, most of these studies were carried out without taking into account the winter navigation condition.

Cold climate countries (Canada, Sweden, Finland, UK, Russia, etc.) can experience harsh winter navigation environment with snow and ice covered roads. Any ADAS, to be effective, should provide collision alert warnings for all weather conditions. Therefore, this paper aims to explore some of the performance of an ADAS system, when used in an urban traffic condition during winter navigation condition (dusk as well as nigh-time). Knowing the real-life limitation of the selected ADAS system will allow further optimization to enhance its capabilities in all weather conditions.

The rest of the paper is organized as follows. The test setup and material are presented in section 2, whereas the results and discussions are presented in section 3 and finally the last section is related to the concluding remarks and future directions.

2 MATERIALS AND SETUP

2.1 Materials

A hydrogen vehicle (see fig. 1) is retrofitted with a Mobileye 5-series intelligent camera. We used this specific type of vehicle because we are investigating the energy efficiency of the fuel cell stack in winter condition (Amamou et al., 2016; Henao et al., 2012; Cano et al., 2014). This system uses a single camera (visible spectrum) which is installed in the middle of the front windscreen. Using a proprietary processor, it can calculate different dynamic parameters related to the vehicle motion (distance between the car and surrounding objects which could potentially be considered as obstacles). The system includes a specific device which serves as a display (EyeWatch) (see fig. 2).

Figure 1: The test vehicle: Hyunday Tucson Hydrogen Vehicle.

The setup is shown in Fig. 3. Mobileye messages are acquired through the Kvaser Leaf device. This device is connected to a computer (Laptop) using one USB port. Three GoPro cameras are also connected to the computer.

To be able to analyze the navigation context adequately and compare the provided Mobileye messages with the human navigation scene interpretation, three monocular GoPro cameras (visible spectrum) were installed. One of them is put on the front windscreen (see Fig. 4). The second one is installed on the vehicle left side whereas the last one is put on the right side. The three cameras provide a surrounding view that help us to interpret each navigation scene. The videos from these cameras are also collected and saved for future analysis.

The GoPro cameras and the Mobileye system are time-synchronized in order to get one common time scale of both vision modalities.

Figure 2: Mobileye Serie 5 with its small display EyeWatch (Mobileye, 2019).

Figure 3: Setup used during the tests in winter condition.

2.2 Naturalistic Test Scenario

To assess the behavior of the intelligent vision system, several tests have been performed during winter 2018 in Canadian urban traffic. The test vehicle used the road shown in Fig. 5. The weather was cloudy at dusk. In the evening and in the night, there is a mixture of rain and snowfall. The visibility is almost poor. No extra warnings were given to the driver and the road users are most likely to be students (going back to home after classes), workers and teachers (going back at the end of the day), nurses, physicians, and other pedestrians. In addition, the driver was asked to ignore the Mobileye messages and drives the car as usual. All grabbed data (from Mobileye Canbus as well as the GoPro cameras) are synchronized to get the same time reference for further analysis.

Figure 4: Camera GoPro installed in front of the test vehicle (middle of the windshield).

The data were segmented into very short datastream of 5s. The idea is to sample the whole urban trip into short motion within the framework of urban navigation. Globally, 2880 samples have been analyzed. For each sample, the analysis consists in:

- processing the sample of Mobileye log file with its corresponding short video;
- identifying the number of detected obstacles in the Mobileye messages stored in the log file;
- for each identified obstacle, check the type of obstacle among vehicle, truck, bike, pedestrian, and bicycle;
- playbacks the corresponding video record from the GoPro camera and assess if the identified obstacle type is really in the video.
- try to find in the video record if there is any potential obstacle which, although it appears in the Mobileye field of view, has not been detected and correctly classified.

3 RESULTS AND DISCUSSION

The following table gives the overall results. Most of the time (97% of the 2880 observation samples), the test vehicle shared the road with other road users (cars, trucks, bikes, bicycles, pedestrians, etc.). As the tests were carried out in winter, very few pedestrians were in the streets (see Table 1).

As reported in Table 2, 2702 samples involves another vehicle (without a pedestrian). The vision system was able to correctly detect and classify all vehi-

Figure 5: Urban test path in a Canada city in Winter. The red color represents the driving road followed by the test vehicle.

Table 1: Global indicators.

Number of samples	2880
Number of samples with another road users (cars, trucks, pedestrians, etc.)	2763
Number of samples with at least one pedestrian	61

cle in the video samples, even when the ambient light was very poor. This good performance of the vision system indicates that the ADAS system is much robust than what the manufacturer advertises.

Table 2: Vehicle detection result.

Number of samples with at least one vehicle (no pedestrian)	2702
Number of samples with a vehicle correctly detected	2702
Number of samples with a vehicle incorrectly detected	0

It has also been observed that 2% of the samples involved a pedestrian. It is critical for safety reason to know how the intelligent vision system can perform in such difficult weather conditions. Therefore, we investigate to know what proportion of the samples with a pedestrian has been correctly classified as having a pedestrian.

Table 3 shows the detail results of pedestrian detection. Among the 61 video samples with at least one pedestrian, 72% were correctly analyzed and classified as having a pedestrian. 20% were incorrectly detected. However, for 8%, we can not assess that the pedestrian was in the Mobileye field of view.

Fig. 6 illustrates a video sample with a pedestrian who is correctly detected and classified at dusk in winter. The sky is cloudy and the ambient light is low, which reduces the contrast between the pedestrian image and the background. This sample has been taken when the test vehicle (Hyundai Tucson Hydrogen Vehicle), after stopping at a road intersection, stated to turn on the left. At the same time, a pedestrian was crossing the intersection and several other vehicles are waiting at the same intersection. It is important to note that when the test vehicle is stopped, the pedestrian worn dark clothes and the asphalt color of the road does not offer a good contrast with the background. In addition, as soon as the vehicle starts turning the pedestrian start crossing the road.

Table 3: Pedestrian detection result.

Number of samples with at least one pedestrian	61
Number of pedestrian samples correctly detected	44
Number of pedestrian samples incorrectly detected	12
Number of pedestrian samples unknown classification	5

The detail interpretation of Mobileye messages that correspond to this video sample is shown in Fig. 7.

Figure 6: Snapshot: Good pedestrian detection at dusk in winter.

In Fig. 7, we showed two graphs. The time scale of both graphs are the same and it corresponds to the sample video ego-time (i.e: the time of the first frame of the video sample is 0). From 0s to 1.2s, the vehicle is stopped at the intersection: it is waiting to turn on the left. Therefore, no important and immediate obstacle has been reported by the Mobileye system. Hence, the first graph (graph (a)) indicates that the number of obstacles is 0 during that time-frame. Thus, no obstacle type is available before 1.2 as shown in the second graph of Fig. 7.

Between 1.2s to 2.4s, the vehicle is turning on its left and the Mobileye system has detected one potential obstacle (y-axis of the first graph shows 1 as the number of detected obstacles.). Note that in the video, the other cars are stopped at the road intersection, waiting their turn to move away. During the same time-frame, the second graph of Fig. 7 indicates that the detected obstacle is likely to be a pedestrian (obstacle type 3). According to Mobileye technical document, the following type of obstacles could be reported:

- Type 0 (binary word 000): the detected obstacle is most likely to be a vehicle
- Type 1 (binary word 001): the detected obstacle is most likely to be a truck
- Type 2 (binary word 010): the detected obstacle is most likely to be a bike
- Type 3 (binary word 011): the detected obstacle is most likely to be a pedestrian
- Type 4 (binary word 100): the detected obstacle is most likely to be a bicycle

The classified pedestrian is true since we can observe in the shown snapshot (Fig. 6) that there was pedestrian crossing the road.

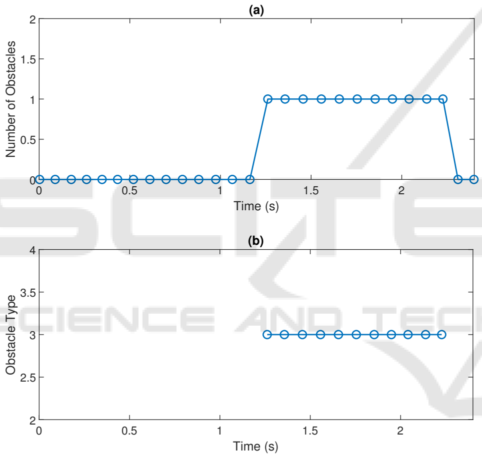

Figure 7: Mobileye message corresponding to the good pedestrian detection at dusk in winter: (a) The number of detected obstacles are reported by the system; (b) The detected obstacle type: 0=Vehicle, 1=Truck, 2=Bike, 3=Pedestrian, 4=Bicycle.

In the snapshot below, the pedestrian on the sidewalk has been successfully detected and classified although the poor contrast between the pedestrian image and the background. It is worth mentioning that there was a drop of snow in front of the camera represented by the white spot in the upper left corner of Fig. 8.

During the tests, several samples with a pedestrian have not been successfully processed. At this time it is very difficult to know what is the most likely reason for these non detection. In the sequel, we illustrated some of the failed pedestrian detections.

Figure 8: Snapshot: Good pedestrian detection during the night in winter.

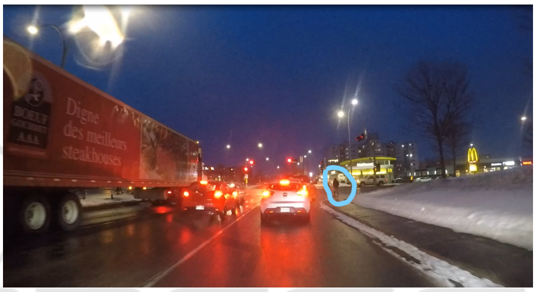

Figure 9: Snapshot: A vehicle is correctly detected and classified but the pedestrian is not detected (see Fig. 10).

In Figs. 9 and 10, the test vehicle is in a traffic during the night in winter. There is a truck on its left and a passenger car in front. In addition, we can observe a pedestrian facing the road and who is start crossing the road (Fig.9). The analysis of Mobileye messages indicates that only one obstacle has been reported (graph (a) of Fig. 9). The type of reported obstacle is ”0” which means that the detected obstacle is most likely to be a vehicle (graph (b) of Fig. 9). Hence the pedestrian is not detected.

In the following figures, we show a case of no detection when the test vehicle was in urban traffic and there were several spotlights into the camera field of view. One car is in front whereas two pedestrians were walking on the sidewalk.

The next figures show a sample with a non-detected pedestrian, although the front vehicle is correctly detected and classified. This sample is taken during the dusk in winter. Indeed, we can observe in Fig. 13 a pedestrian crossing the road on the left. The test vehicle is waiting to turn on the left. The analysis of Mobileye messages indicates in Fig. 14 that the number of reported obstacles is 1 (see graph (a)) and the type of the detected obstacle is 3 which means that the front vehicle is detected. However, the crossing pedestrian, although he was walking on the road, no specific detection has been reported.

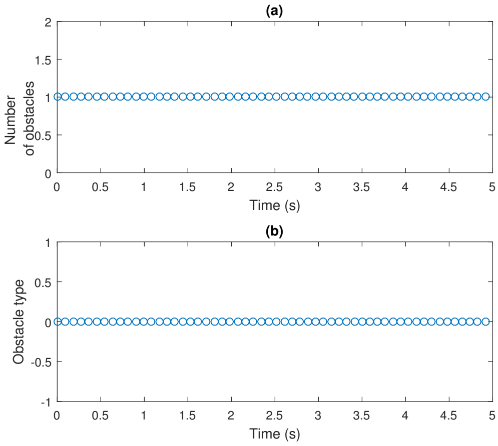

Figure 10: Mobileye signal interpretation: (a) The number of reported obstacles is 1. (b) The obstacle type is a vehicle. Clearly the pedestrian near the vehicle in front is not detected as shown in the snapshot (see Fig. 9).

Figure 11: Snapshot: The vehicle in front and the two pedestrians are not detected (see Fig. 12).

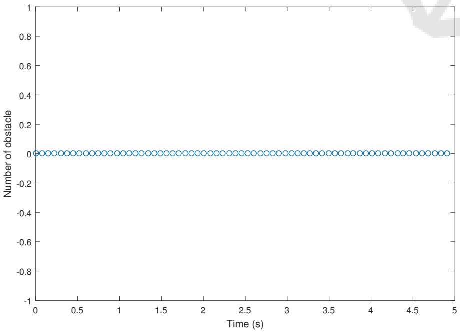

Figure 12: Mobileye signal interpretation: The number of reported obstacles is 0.

4 CONCLUSION AND FUTURE WORKS

In this work, one of the most used vision systems for advanced driving assistance system (Mobileye) has been tested in winter condition and urban traffic. Using additional cameras, the performance of this advanced vision system has been assessed in harsh environmental conditions. The test started during winter dusk and covered different lighting and weather conditions. In general Mobileye vision system provides good detection accuracy for cars and other vehicles (more than 99night seems to be more difficult to achieve. In future work, an in-depth analysis of which pedestrian characteristics are most likely to have a significant impact on the detection accuracy in winter will be carried out. Besides, we will investigate the combination of a thermal vision system with the Mobileye vision system to increase the pedestrian detection and classification accuracy

Figure 13: Snapshot: The vehicle in front and the two pedestrians are not detected (see Fig. 14).

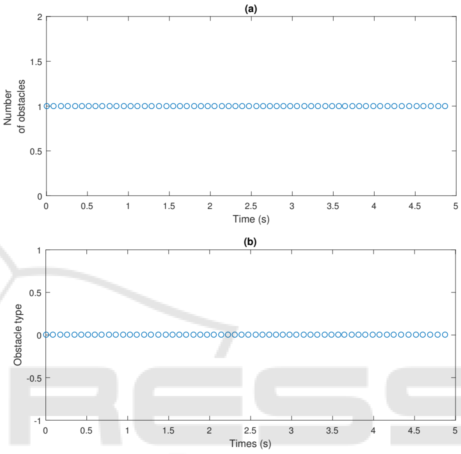

Figure 14: Mobileye signal interpretation: The number of reported obstacles is 0.

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REFERENCES

Abelson, P. (2012). Playing it safe. *Concrete Producer*, 30(1).

Amamou, A. A., Kelouwani, S., Boulon, L., and Agbossou, K. (2016). A comprehensive review of solutions and strategies for cold start of automotive proton exchange membrane fuel cells. *IEEE Access*, 4:4989–5002.

Barclay, S. (2012). Mobileye to launch the world's first smartphone-connected driver assistance system. *Automotive Industries AI*, 192(1).

Birrell, S. A., Fowkes, M., and Jennings, P. A. (2014). Effect of using an in-vehicle smart driving aid on real-world driver performance. *IEEE Transactions on Intelligent Transportation Systems*, 15(4):1801–1810.

Cano, M. H., Kelouwani, S., Agbossou, K., and Dubé, Y. (2014). Free air breathing proton exchange membrane fuel cell: Thermal behavior characterization near freezing temperature. *Journal of Power Sources*, 246:650–658.

Chang, B., Tsai, H., and Young, C.-P. (2010). Intelligent data fusion system for predicting vehicle collision warning using vision/gps sensing. *Expert Systems with Applications*, 37(3):2439–2450.

Chang, B., Young, C.-P., and Tsai, H. (2009). Simulation and implementation of high-performance collision warning system for motor vehicle safety using embedded anfis prediction. *International Journal of Innovative Computing, Information and Control*, 5(10):3415–3430.

Chen, B., Zhao, D., and Peng, H. (2017). Evaluation of automated vehicles encountering pedestrians at unsignalized crossings. pages 1679–1685.

Curiel-Ramirez, L., Ramirez-Mendoza, R., Carrera, G., Izquierdo-Reyes, J., and Bustamante-Bello, M. (2018). Towards of a modular framework for semi-autonomous driving assistance systems. *International Journal on Interactive Design and Manufacturing*, pages 1–10.

Excell, J. (2005). Sens-ational drive. *Engineer*, 293(7668):30–31.

Fireman, M. (2017). Mobileye to generate, share, and utilize vision data for crowdsourced mapping with nissan. *Automotive Industries AI*, 197(4).

Henao, N., Kelouwani, S., Agbossou, K., and Dubé, Y. (2012). Pemfc low temperature startup for electric vehicle. In *IECON 2012-38th Annual Conference on IEEE Industrial Electronics Society*, pages 2977–2982. IEEE.

Ke, R., Lutin, J., Spears, J., and Wang, Y. (2017). A cost-effective framework for automated vehicle-pedestrian near-miss detection through onboard monocular vision. volume 2017-July, pages 898–905.

Larkin, J. (2006). Mobileye vision technologies providing applications for delphi's collision mitigation system. *Automotive Industries AI*, 186(4).

Lee, M., Lim, W., Kim, S., and Sunwoo, M. (2018). Temporal local route modeling using the recognized lane for autonomous driving comfort.

Lyu, N., Deng, C., Xie, L., Wu, C., and Duan, Z. (2018). A field operational test in china: Exploring the effect of an advanced driver assistance system on driving performance and braking behavior. *Transportation Research Part F: Traffic Psychology and Behaviour*.

Markwalter, B. (2017). The path to driverless cars [cta insights]. *IEEE Consumer Electronics Magazine*, 6(2):125–126.

Mobileye (2019). Mobileye serie 5, https://www.mobileye.com/fr-fr/produits/mobileye-serie-5/.

Reagan, I. (2019). Effects of an aftermarket crash avoidance system on warning rates and driver acceptance in urban and rural environments. *Advances in Intelligent Systems and Computing*, 786:776–787.

Thompson, J., Mackenzie, J., Dutschke, J., Baldock, M., Raftery, S., and Wall, J. (2018). A trial of retrofitted advisory collision avoidance technology in government fleet vehicles. *Accident Analysis and Prevention*, 115:34–40.

Vasic, M., Mansolino, D., and Martinoli, A. (2016). A system implementation and evaluation of a cooperative fusion and tracking algorithm based on a gaussian mixture phd filter. volume 2016-November, pages 4172–4179.

Wang, J.-G., Zhou, L., Song, Z., and Yuan, M. (2017). Real-time vehicle signal lights recognition with hdr camera. pages 355–358.

Wright, C. (2016). Mobileye to offer user-generated mapping for autonomous driving: New technology will allow drivers to provide real-time road information to enhance autonomous driving experience. volkswagen and general motors first strategic partners to explore this technology. *Automotive Industries AI*, 196(1).