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Optical Flow Based System for Cross Traffic Alert

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***Abstract*—**This document describes an advanced system and methodology for Cross Traffic Alert (CTA), able to detect vehicles that move into the vehicle driving path from the left or right side. The camera is supposed to be not only on a vehicle still, e.g. at a traffic light or at an intersection, but also moving slowly, e.g. in a car park. In all of the aforementioned conditions, a driver's short loss of concentration or distraction can easily lead to a serious accident. A valid support to avoid these kinds of car crashes is represented by the proposed system. It is an extension of our previous work, related to a clustering system, which only works on fixed cameras. Just a vanish point calculation and simple optical flow filtering, to eliminate motion vectors due to the car relative movement, is performed to let the system achieve high performances with different scenarios, cameras and resolutions. The proposed system just uses as input the optical flow, which is hardware implemented in the proposed platform and since the elaboration of the whole system is really speed and power consumption, it is inserted directly in the camera framework, allowing to execute all the processing in real-time.

***Keywords*—**Clustering, cross traffic alert, optical flow, real time, vanishing point.

I. Introduction

A wide range of advanced technologies are currently being introduced into production automobiles, investing a lot in terms of innovation about many aspects regarding Advanced Driver Assistance System (ADAS). An ADAS is a vehicle control system that uses environment sensors (e.g. radar, laser, infrared and normal cameras) to improve traffic safety by assisting the driver in recognizing and reacting to potentially dangerous traffic situations. Different types of intelligent vehicle systems can be distinguished: driver information systems, like advanced route navigation systems [1]; driver warning systems, like Lane Departure Warning (LWD) [2], Collision Avoidance (CA) [3], Blind Spot Detection (BSD) [4]; intervening systems, like Adaptive Cruiser Control (ACC) [5].

In particular, driver warning systems actively warn the driver of a potential danger, allowing the driver to take appropriate corrective actions in order to mitigate or completely avoid the event. Among these systems, apart for security, CTA is an important system to reduce stress [6]. It is designed to alert drivers, usually with acoustic warning signal sounds, for encroaching vehicles in different situations, like backing out of parking spaces and slowly arriving/leaving to traffic lights or crossroads. Physical limitation of CTA is that the sensors cannot reveal obstructing objects or vehicles in the scene, so in this case cannot properly work.

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CTA requires efficient algorithms and methods for real-time processing. A range sensor mounted on the vehicle could provide a practical solution to the problem. Typically, a radar sensor [7] and both radar and image sensors [8] have been proposed for this purpose. These systems reach good performances, but they are too expensive to enter the automotive mass market. Interesting approaches to the problem are the data fusion techniques, which combine information from several sensors in order to provide a complete view of the environment. Different well performing approaches have been proposed: image infrared and visible light sensors [9], object detection sensor (radar or camera) and in-vehicle sensor (for steering wheel and speedometer) [10], and so on. Unfortunately, these cheaper systems are not so cheap to be suitable for a potential automotive mass market.

Today, the newest cars present in the market, make use of back, forward and sides cameras for different purposes, but since we are interested in really low-cost systems, we focused our attention only to single low cost image cameras. Different approaches have been proposed: histogram back-projection based road-plane segmentation, based on saturation and value channels of the video [11]; video based size and position of the vehicle [12]; vehicle detection based on Haar and Adboost and camera calibration [13]; Bayes classifier and shadow detection with symmetry-based approach [14]; Haar-like feature and Adaboost classifier, together with Support Vector Machine (SVM) classifier with Histogram of Oriented Gradients (HOG) feature [15]; SVM classifier [16] and so on. At system level, these approaches are typically based on combination of image sensor and image processor [17] and usually Engine Control Unit (ECU) with multi-core (Micro Controller Unit) MCU [18] to intensively elaborate image data.

The proposed solution for CTA is low cost camera based and instead of working on image information, it is entirely based on optical flow, extracted from the scene. Since a growing number of manufactures produce image sensors with hardware implemented optical flow [19], the system can work directly in the Image Signal Processor (ISP), avoiding overloading the ECU and to transmit the entire image flow, without the need to have an external image processor. It allows obtaining a real time CTA application with really low extra computational effort, with good performances.

The rest of the paper is organized as follows: Section II presents the schema of the proposed CTA system and detailed description of the three main blocks in which it is composed (vanishing point, horizontal filter and clustering); Section III reports the hardware setup used to implement the proposed CTA system and the experimental results, compared to our previous clustering system [20]; Section IV describes the final remarks related to proposed system; at last, Section V lists the various references used in this paper, useful for further investigation.

II. Algorithm

The proposed advanced low cost CTA system is basically shown in Fig. 1. As mentioned in the introduction, the CTA system should work directly in the ISP of the Camera, without the need to have an external Image Processor. The alert can be of different types as acoustic, visible, haptic or a mixing of them. In this proposal, for the sake of clearness, we used the visible warning. In particular, we realized an output video showing the input scene where the detected crossing vehicles are surrounded by a bounding box.

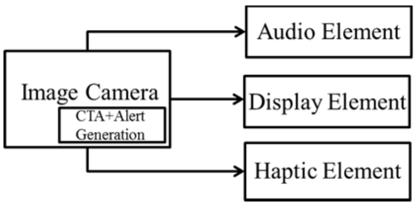

Fig. 1 Block based schema of the proposed system

The block based schema of CTA algorithm is shown in Fig. 2. In particular, the proposed CTA algorithm is feature based, using the Optical Flow (OF), e.g. the collection of Motion Vectors (MVs) indicating the motion of a feature in the current frame compared with the same feature in the previous frame. The OF is computed directly inside the ISP of the camera, ensuring a real time processing.

As indicated in Fig. 2, the steps of CTA algorithm are the following:

1. Vanishing Point (VP) calculation. This step takes in input the optical flow OF and filters the related motion vectors to obtain the zoom vectors, e.g. the vectors lying in the road. Afterwards, the VP is calculated. It is the mean point of all intersections of straight lines passing through the zoom vectors. At last, to increase robustness of the VP calculation, a temporal VP averaging is done.
2. Horizontal filter. This step takes into account the VP previously calculated in Vanish Point calculation, the Bound Box (BB) list of previous frames calculated on previous Clustering step and the whole set of optical flow OF. In this step, the motion vectors of set OF are divided into two sub-sets: the motion vectors inside previous Bound Box List, which are preserved and inserted in output optical flow set OF' and the motion vectors outside previous Bound Box List, which are horizontally filtered and eventually inserted in output OF' set.
3. Clustering. This step takes in input the optical flow OF', which is a horizontally filtered set from optical flow OF. In this step, set OF' is filtered to eliminate noisy motion vectors and all filtered motion vectors are labelled depending on their spatial location, module and orientation. At the end, the motion vectors with the same label are grouped into clusters. In this way, moving vehicles in the scene are identified, and the final bounding box BB list is obtained as output, ready to be eventually displayed in the scene. When the BB list is not empty, an acoustic or haptic alert can be also generated.

In the following subsections, the aforementioned steps will be detailed described.

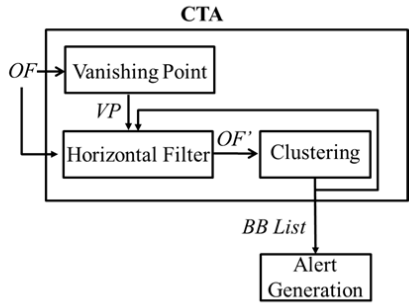

Fig. 2 Block based schema of the CTA algorithm

A. *Vanishing Point*

A very useful scene information in video analysis is the VP position, since it allows to determine the horizon of the scene. From a theoretic point of view, the VP position into the scene overlaps the center of the image only in a case of an ideal situation: a road perfectly plane (no slopes and no curves), a forward camera placed horizontally to the ground (no tilt angle), and perpendicularly to the main car axis (no pan angle).

The real case (this is the target scenario for the proposed application) presents the camera calibration parameters different to zero (tilt and pan angles) and, mainly, the host car crosses through roads which can have slopes and curves. Therefore, in a real environment, the VP position does not coincide with the center of the image and for this reason it is estimated.

In this proposal, the VP position is important not only because delimits the horizon of the scene, but also because it contributes to the selection of the motion vectors potentially belonging to a crossing vehicle in the next Horizontal Filter sub-block.

The VP is computed using only the optical flow. The developed procedure is schematically represented in Fig. 3 and it can be synthetized as follows:

1. Zoom-out filter. The input OF is filtered, according to the motion vectors orientation. Only the zoom vectors, that is motion vectors laying on the road, are selected constituting the OF'' set.
2. VP calculation. VP is calculated for each frame as the average position of all exhaustive intersections among lines generated by directions of motion vectors belonging to the OF'' set [21].
3. VP Check. The VP estimated in the current frame will contribute to the VP, which is the temporal position estimation, only if it passes a specific check. Overlying a 3x3 grid over the image, if the VP position of the current frame belongs to the central area of the grid, then it will be used for the temporal average VP', otherwise it will be discarded.

4. Temporal Averaging. The arithmetic media between valid VP positions relative to subsequent frames are calculated [22]. Due to the presence of outlier in the zoom-out set, the subsequent VP positions can be slightly different. The temporal approach allows smoothing these differences ensuring a more reliable and steady VP. The temporal VP' position is initialized to the center of the image plane and it reaches its stable position in few frames. Tests reveal that, just after around 10 frames, the calculated VP converges. Moreover, compared to a ground truth, the calculation of VP' reaches a really good accuracy.

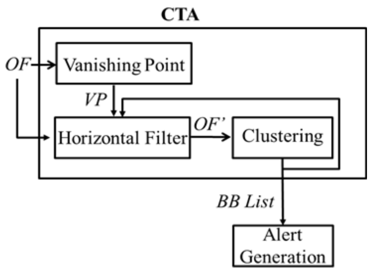

Fig. 3 Block based schema of VP step

B. Horizontal Filter

To let the subsequent Clustering step correctly work, since it works only with steady camera, it is important to remove from optical flow OF all the motion vectors which are in the same direction of the vehicle movement, so filtering the horizontal motion vectors.

We propose a filtering based on bounding box BB list of previous frames, calculated temporal VP and motion vectors orientations of optical flow OF. The proposed Horizontal Filter is composed by the following steps, as indicated in Fig. 4:

1. BB Check. It works on optical Flow OF set. All the motion vectors inside previous calculated bounding box BB list are preserved, to avoid eliminating true clusters in the next Clustering step. Of course, these motion vectors can be motion compensated, assuming a constant speed in the scene. It is a vital step. In fact, motion vectors in vehicles in the left side of the scene moving to the left (and vehicles in the right side of the scene moving to the right) can be easily confused with motion vectors to be eliminated, related to the vehicle movement. Introducing the BB Check step, we overcome this problem, assuming that vehicles in the left side of the scene moving to the left (and vehicles in the right side of the scene moving to the right) were previously situated in the scene, moving starting from opposite side of the scene and then previously identified by Clustering step. Without this step, there is the risk in our tracking to lose some previously identified vehicles, with a significate drop of overall performances.
2. Horizontal Check. This block filters the horizontal motion vectors of optical flow OF. A vector is retained, that is considered horizontal, if two conditions are both satisfied:

2a. Its orientation lies around horizontal orientation (zero or 180 degree), as indicated in Fig. 5. In our experiments θ=ρ =10 degree.

2b. The orientation difference between the considered motion vector orientation and the orientation of the same motion vector translated on temporal VP overcomes an evaluated dynamic threshold *TH*, as indicated in Fig. 6. This dynamic threshold *TH* can be valuated as percentage of the difference between maximum and minimum orientation lying around the considered motion vector, $|\alpha-\beta|<TH$. In particular, for each motion vectors, the neighborhood considered to calculate the threshold *TH* is set to ±1 in both directions.

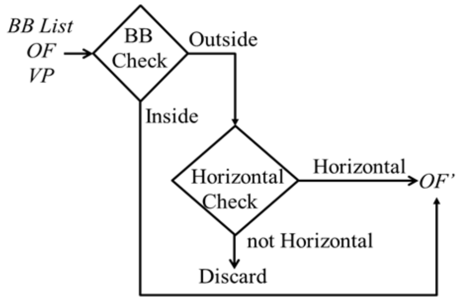

Fig. 4 Block based schema of Horizontal Filter step

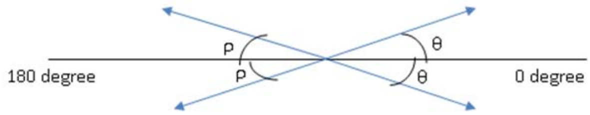

Fig. 5 First Horizontal Check condition

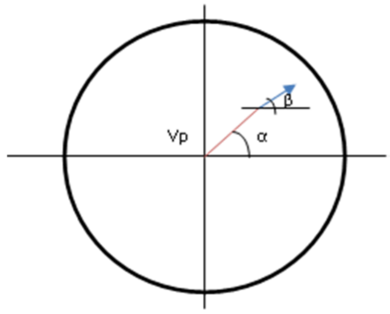

Fig. 6 Second Horizontal Check condition

C. Clustering

In CTA, application is important to group moving cars transversally approaching our vehicle in the same cluster.

As mentioned, the proposed clustering step works on only optical flow analysis and it is based our previous work [22]. It is composed by the following steps, as indicated in Fig. 7:

1. Pre-filtering. This starting step takes as input the optical flow OF', filtered by previous Horizontal filer block. Its role is to remove from this optical flow set OF' all vectors which can be considered as noise, obtaining an optical flow sub-set OF'''. Usually complex filtering is used as for example median filters [23] and so on. Since we are interested in really low power solution, we used the

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suggested brute-force algorithm option [20]. It just eliminates motion vectors with really small movements, which are considered as noise. The chosen range is [-1 .. +1].

2. Labelling. In the same cluster, there are only motion vectors which have the same label. To have the same label, two or more motion vectors have got similar module and are spatially near. Another condition, which is to have got similar orientation [20], has been added for the reliability of the system.
3. Clustering. This step takes two inputs: the filtered optical flow OF''', coming from previous pre-filtering elaboration and the labels of the motion vectors contained in OF''', obtained by previous labelling step. Clusters are identified, according to the labels of the motion vectors. Of course, vectors with same label are grouped in the same cluster. Depending on the type of the camera and the distance from the object, clusters can be extended to a minimum vertical and horizontal size [20].
4. Merge Clustering. In a similar way of labels in labelling step, two clusters are considered similar and then merged if they are spatially near, have got similar module and orientation [20].

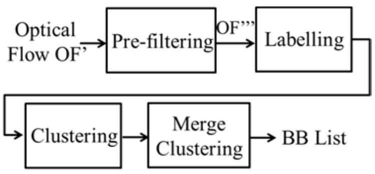

Fig. 7 Block based schema of Clustering step

III. Experimental Results

Lots of tests have been executed with different scenarios and different cameras at different resolutions, with both linear and fish-eye lens, obtaining really good visual results.

Let us show some examples, obtained with the abovementioned environment. An example of Rear CTA with fish-eye lens camera is shown in Figs. 8 and 9. In Rear CTA case, the camera is mounted on the back of the vehicle and we are backing out of parking spaces. The output of just Clustering system [20] (Fig. 8) shows false bounding boxes on the ground, since the camera is mounted in a moving car and lines on the ground are moving; while, with the proposed CTA solution (Fig. 9) these false bounding boxes are eliminated, since they are correctly identified and removed by Horizontal Filter.

Another example shows slow crossroad vehicle arriving with linear lens camera, as displayed in Figs. 10 and 11. In this case, the camera is mounted in front of the vehicle and we are slowly approaching to a crossroad. The output of just Clustering system (Fig. 10) shows false bounding boxes on the ground, on the leaves of trees and in the road sign; while, with the proposed CTA solution (Fig. 11) all these false bounding boxes are removed, correctly leaving the correct bounding boxes in the two crossing cars.

Fig. 8 Rear CTA example: Clustering output

Fig. 9 Rear CTA example: CTA output

Fig. 10 Crossroad arriving example: Clustering output

Fig. 11 Crossroad arriving example: CTA output

Fig. 12 Crossroad leaving example: Clustering output

Fig. 13 Crossroad leaving example: CTA output

Last example shows slow crossroad vehicle leaving with linear camera lens, as displayed in Figs. 12 and 13. In this case, of course, the camera is mounted in front of the vehicle and we are slowly leaving a crossroad. The output of just Clustering system (Fig. 12) shows false bounding box on the ground and on the leaves of trees; while, with the proposed CTA solution (Fig. 13) all these false bounding boxes are removed, as usual, correctly leaving the bounding boxes in the crossing car.

IV. Conclusion

In this paper a Control Traffic Alert (CTA) system has been proposed. It is able to alert when it detects vehicles that move into the vehicle driving path from the left or right side. Typical scenarios are: slowly arriving or leaving to crossroads and traffic lights and backing out of car park spaces. The alert sent from the system can be of different types as acoustic, visible, haptic or a mixing of them.

The proposed CTA approach has been experimentally tested on a representative dataset of scenes obtaining effective results in terms of accuracy. Some examples with different cameras and in different conditions have been shown to demonstrate the robustness of the proposed system.

At last, the proposed system is also very flexible because it can be used with any algorithm which estimates motion vectors between adjacent frames, to obtain the related optical flow. Also, VP calculation and clustering algorithm can be replaced with any other approaches.

References

[1] S. Jeong, T. Kim, J. Lee, S. Lee and J. Lee, "Design analysis of precision Navigation System", 12th International Conference on Control, Automation and Systems, ICCAS, Jeju, South Korea, pp. 2079-2082, October 16-19, 2012.
[2] T. Aung and M. H. Zaw, "Video Based Lane Departure Warning System", International Conference on Advances in Engineering and Technology, Singapore, March 29-30, 2014.
[3] A. Choudhary, Y. Moon and R. Nawkhare, "Design and Implementation of Wireless Security System in Vehicle", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 3, Issue 7, July 2015.
[4] B. F. Wu, C. C. Kao, Y. F. Li M. Y. Tsai, "A Real-Time Embedded Blind Spot Safety Assistance System", International Journal of Vehicular Technology, Volume 2012, Article ID 506235, 2012.
[5] P. Shakouri, J. Czeczot and A. Ordys, "Adaptive Cruise Control System using Balance-Based Adaptive Control technique", 17th International Conference on Methods and Models in Automation and Robotics, MMAR, Miedzyzdroje, Poland, August 27-30, 2012.
[6] B. Reimer, B. Mehler and J. F. Coughlin, "An Evaluation of Driver Reactions to New Vehicle Parking. Assist Technologies Developed to Reduce Driver Stress", New England University Transportation Center, White Paper, November 2010.
[7] T. Komoguchi, T. Kawasaki, Y. Takahashi, "Rear cross traffic alert device", US 2014/0015693 A1, USA, 2014.
[8] S. Zeng, "Cross traffic collision alert system", US 2011/0133917, USA, 2011.
[9] J. Thomanek and G. Wanielik, "A new pixel-based fusion framework to enhance object detection in automotive applications", 17th International Conference on Information Fusion, FUSION, Salamanca, Spain, July 7-10, 2014.
[10] S. Zeng, J. A. Salinger, and P. V. Ganesan, "Method and apparatus for rear cross traffic collision avoidance", US 2008/0306666 A1, USA, 2008.
[11] R. Tan, "A safety concept for camera based ADAS based on multicore MCU", IEEE International Conference on Vehicular Electronics and Safety, ICVES, Hyderabad, India, December 16-18, 2014.
[12] E. Dagan, O. Mano, G. P. Stein and A. Shashua, "Forward collision warning with a single camera", IEEE Intelligent Vehicles Symposium, pp. 37-42, July 2004.
[13] J. Cui, F. Liu, Z. Li and Z. Jia, "Vehicle Localisation Using a Single

Camera", IEEE Intelligent Vehicles Symposium, August, 2010.
[14] Y. Jheng, Y. Yen and T. Sun, "A symmetry-based forward vehicle detection and collision warning system on Android smartphone", IEEE International Conference on Consumer Electronics, Taiwan, ICCE-TW, Taipei, Taiwan, June 6-8, 2015.
[15] Y. Deng, H. Liang, Z. Wang and J. Huang, "An integrated forward collision warning system based on monocular vision", IEEE International Conference on Robotics and Biomimetics, ROBIO, Bali, Indonesia, December 5-10, 2014.
[16] E. Salari, and D. Ouyang, "Camera-based Forward Collision and lane departure warning systems using SVM", IEEE 56th International Midwest Symposium on Circuits and Systems, MWSCAS, pp. 1278-1281, 2013.
[17] C. A. Green, and U. H. Balbale, "Cross traffic alert system for a vehicle, and related alert display method", US 2010/0201508 A1, USA, 2010.
[18] V. Balisavira and V. K. Pandey, "Real-time Object Detection by Road Plane Segmentation Technique for ADAS", Eighth International Conference on Signal Image Technology and Internet Based Systems, SITIS, November 2012.
[19] A. A. Stocker and R. J. Douglas, "Analog integrated 2-D optical flow sensor with programmable pixels", Proceedings of the 2004 International Symposium on Circuits and Systems, ISCAS,Vancouver, Canada, May 23-26, 2004.
[20] G. Spampinato, A. Bruna, S. Curti and V. D'Alto, "Advanced Low Cost Clustering System", 6th International Conference on Image Processing Theory, Tools and Applications, IPTA, Oulu, Finland, December 12-15, 2016.
[21] N. Takeda and M. Watanabe, "Device and method for detection of moving obstacles", US 5777690 A, USA, 1998.
[22] M. Jähnisch, M. Siebeneicher, A. Fietz, A. Haja, D. Liebehenschel and C. Söhnel, "Method and apparatus for calibration of a camera system of a motor vehicle", DE102014209137 A1, Germany, 2015.
[23] S. Aslani and H. Mahdavi-Nasab, "Optical Flow Based Moving Object Detection and Tracking for Traffic Surveillance", World Academy of Science, Engineering and Technology International Journal of Electrical, Robotics, Electronics and Communications Engineering, Vol. 7, No 9, 2013.