THE ANNALS OF "DUNĂREA DE JOS" UNIVERSITY OF GALAȚI
FASCICLE V, TECHNOLOGIES IN MACHINE BUILDING,
ISSN 1221-4566, 2011

VIDEO COLLISION WARNING SYSTEM BASED ON TOPOLOGICAL APPROACH

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Abstract

The objective of this research is to develop a driver warning system with collision warning (CW) functions. The system is mainly configured with a CCD camera to acquire the images of roadway ahead in association with an image-processing computer. The input image captured by a camera is used to recognize the possible obstacles represented by cars and pedestrians and to predict the possible collision trajectory. Therefore, the system is able to issue real-time auditory and visual output warnings when a driver is getting too close to cars or pedestrians in order to prevent a possible danger. The proposed method in this paper deals with the detection of obstacles using topological approach.

KEYWORDS: collision warning systems, intelligent auto

1. Introduction

The method described in this paper is the extension of a previous research considering collision avoidance. In the case of 3D machine measurement, there is the risk of collision of the probe to different obstacles that leads to the break or decalibration of machine's components [Fig.1]. A method based on computer vision was proposed. The system is able to warn the user in case of imminent collision.

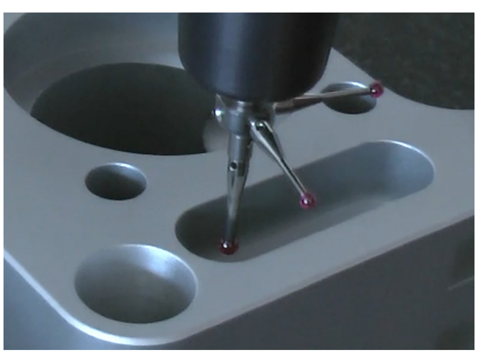


Fig. 1. *Probes in the 3D measurement machine*

In the case of unknown topological structures explored by the 3D measurement machine, there is a high risk of accidental collision. The software application developed serves as a watchdog that warns the user if the probe is in imminent collision with any obstacle including the part to be measured.

One of the most promising applications of computer vision is the vision-based vehicle collision detection for driver assistance. There are several reasons for implementing computer vision based on driver assistance: first, the huge losses both in human lives and finance caused by vehicle accidents; second, the availability of reliable algorithms in computer vision.

Frontal collision warning/collision avoidance systems (FCWS) refer to the early warning/early action in the case of an important crash type: rear-end crashes with a vehicle.

FCWS monitor the host vehicle and the vehicle ahead and warn the driver about the impeding crash. This technology uses the sensors and computer vision system to predict the speed of the monitored vehicle, and the distance between two vehicles. When the distance is short, the driver is alerted in order to prevent the crash. The system provides the diver with audible alert, visual display or other alerts.

In U.S.A., the percentage of rear end collision in all collisions was about 31.5% in 2009. The statistics show that about 80 percent of the drivers have not performed any action at impact. In the

European Union about 10.000 pedestrians and cyclists are killed and about 500.000 injured. 50 percent of the accident occurred at an impact below 48 km/h. In Japan approximately 4000 pedestrians and cyclists are killed and about 30.000 injured each year. Though the speed that causes these accidents is very low, the amount of both human losses and finance is important. Therefore a system to prevent or diminish an accident is a must have for the future auto industry.

Nowadays, different companies have successfully implemented collision warning systems and include or are based exclusively on computer technologies (Fig.2).

Toyota Motor Corporation's Pre-Collision System (PCS) is the first production of a forward warning collision system, it is a radar-based system which uses forward-facing millimeter-wave radar.

In 2004 Toyota implemented a system by adding to the radar a single digital camera to improve detection accuracy of collision which was available on Crown Majesta.

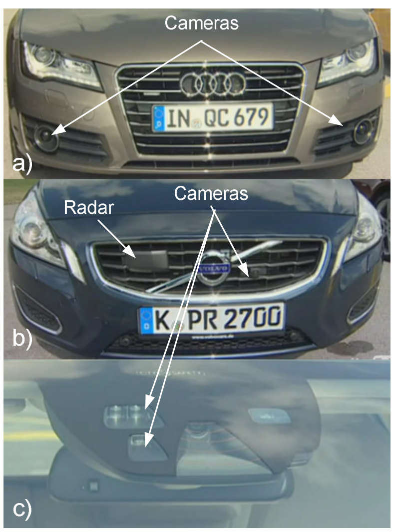


Fig. 2. *Different approach to camera and sensor fusion in commercial implementation: a) Audi cameras are placed in the front bumper b) Volvo cameras are using radar along with cameras placed both in front bumper and also in c) in rear mirror*

Front Assist on the 2011 Volkswagen Touareg is able to brake to a stop in case of an impending crash and also the system tension the seatbelts. Also Audi releases such a system on top models (A8).

Available since 2010 in the Volvo S60 and V60 Fig. 2 b, c, as well as Mobileye’s after market system, the Pedestrian Collision Warning system serves to warn the driver about a potential collision with vehicles and pedestrians.

Volvo's Collision Warning with Auto Brake CWAB) developed in cooperation with Mobileye system warns the driver if there is a potential collision between the host vehicle and the pedestrian. If the driver does not react and a collision is unavoidable, then the cameras and the radar system will make a braking decision once the radar has confirmed the obstacle. All systems are active only during the day. Ford, Acura, Opel, Mercedes companies had their own forward collision warning system.

Different methods using feature-based approach are applied to detect vehicle ahead using features such as texture, edge, symmetry and shadow of vehicle images.

There are several approaches concerning pedestrian detection, such as support vector machine [2], 3D data space reconstruction [3], [4] and other approaches [4], [5]. Last but not least, flow algorithm is used for collision detection [6].

The objective of this research is to develop an advanced driver assistance system with the functions of collision warning (CW). The system is mainly configured with a CCD camera to acquire the images from roadway and the images are processed by an onboard computer.

The input image captured by a camera is used to recognize the possible obstacles represented by cars and pedestrians and to predict a possible collision trajectory. Therefore, the system is able to issue real-time auditory and visual outputs of warning when a driver is getting too close to approach to cars or pedestrians in order to prevent the accident. FCWS provide audible and/or visual warnings of vehicles or objects that come within a predefined predicted distance in front of the vehicle equipped with such a system.

2. Applying the method

We propose in this paper a complete framework for identifying obstacles based on their underlying topology. The identifying method is based on the invariant structure of each class of form features and on its topological evolution of motion.

Identifying objects in the image method is based on the idea that the objects are topological entities comprising simple geometric shapes in certain location relations between the shapes. The shapes are defined as cvasi-geometric shapes (Fig. 3). For instance, rectangles are identified as shapes comprised of 4 connected lines, the angle between the two lines is about 90 percent (with a tolerance of 10%) and the sum of all angles should be 360 degrees.

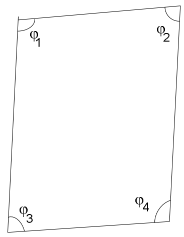


Fig. 3. *Representation of cvasi-rectangle*

The features of each geometric shape are described in Fig.11, Fig.12, Fig. 13. Each obstacle, generic car and generic pedestrian is described as shown in Fig.5.

On one hand, the generic car is described as a 3D representation and, on the other hand, the pedestrian is described as a geometric topological structure but also as a topological motion structure (Fig. 5). Concerning the motion, the legs movement is in a relation of movement which defines the entity structure (Fig. 5).

In our approach, a topological entity is defined by two perspectives: one concerning the geometric basic shapes relations but also the motion’s relation between the geometric shapes. The motion is viewed as a way of interaction and inter-relation between the elements of the entity.

In Fig. 4 is shown the similarity between geometric topology structure and motion topology.

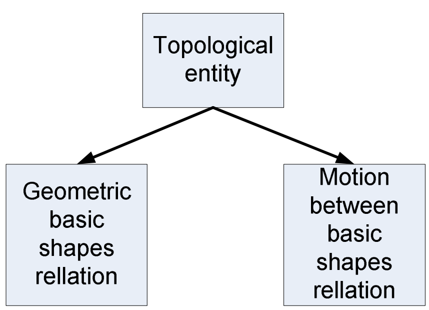


Fig. 4. *Topological entity proposed for this approach: geometric and motion based structures*

The successive frames are seen as the third dimension and the motion defines elements of topological structure. If the cylinder and parallelepiped are elements of the geometrical topological entity, in the case of motion topological entity, the successive pedestrian position represents the elements of the topological entity.

The cylinder and the parallelepiped lie in a certain relation of positioning and are characterized by their geometrical parameters, in the same way the successive position of the “pedestrian” lies in certain relations to each successive frames. Each side is a topological structure described as in Fig. 11, Fig. 12, Fig. 13.

System structure

The sensing device is a web camera mounted between the front windshield and the rear-view mirror inside the car (Fig. 6). The camera acquires the roadway images in front of the vehicle and transfers the acquired images to a computer for processing, analyzing the images and identifying the objects ahead the vehicle. With this hardware structure configured with collision warning system function, as shown in Fig. 7, the goal of obstacle detection is achievable by applying the real-time image-processing method.

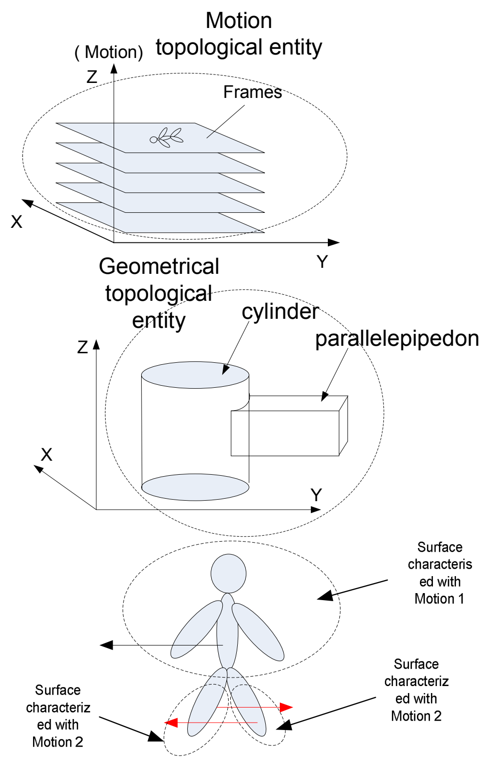


Fig. 5. *Similarity between geometric and motion topology*

The software was developed in Visual Studio 2008 IDE using C language and OpenCV computer vision library. The camera used is Logitech - HD Pro Webcam C910 and the working resolution used was 800X600 pixels. The algorithm processed a frame in about 200 ms on a Celeron 1.6 Pentium IV) processor. The laptop Toshiba Satellite L30-134 (1 Gb memory) laptop computer was chosen in order to test the method to relatively low computer resources, architecture suitable for a on-board vehicle computer.

Fig. 6. *Test vehicle*

Figure 7 gives an overview of the algorithm for feature extraction and matching. In our target application, a new image must be matched with one description.

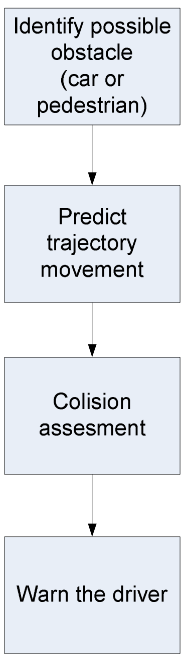


Fig.7. *Collision detection software steps*

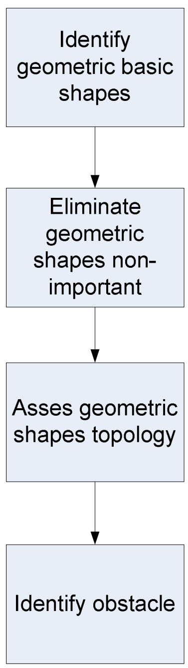
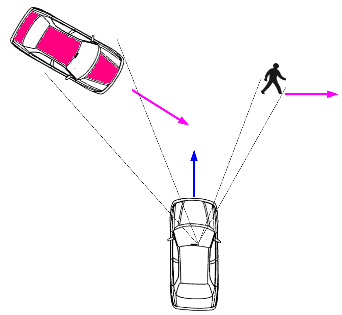


Fig. 8. *Obstacle detection algorithm*

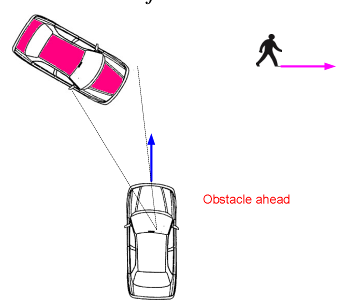
The algorithm in detecting the obstacle in front of the vehicle is represented by several steps as described in Fig. 8. The possible obstacles are identified with the method described in this paper, based on topological approach, the trajectory is predicted for each possible obstacle (the trajectory estimation is subject to a future paper). Afterwards, if the distance to obstacle is becoming closer and there are collision trajectories of the vehicle and the obstacle, then the warning is issued.

We try to achieve high-speed execution of the algorithm, where the localization takes place in order to allow not only real time image processing for the collision detection but also to have enough computational resources left to later add other features such as traffic sign recognition or lane departure.

The algorithm based on topological approach is described in Fig.7. The basic geometric shapes are identified (cvasi-rectangle and cvasi-circle) in the first step. In the second step, the shapes that are too small (are either too far objects or not important static objects) are not considered.



a) identifying possible obstacles and predicting trajectories



b) the predicted collision trajectory is tracked and in the case of an eminent collision then the obstacle ahead warning is issued

Fig. 9. *Scenario for collision detection*

The topology is the assessment with the rules described in Fig.11, Fig.12, Fig. 13. If the topological entities are found then the objects are tracked frame to frame in order to evaluate the trajectory.

The authors imagined several scenarios as presented below (Fig. 14, Fig. 15, Fig. 16).

We tested the vehicle with CWS running into a parking car at speed up to 40 km/h. We also tested the system in traffic and the driver was warned if the distance to the front obstacle was less than 10 meters. Also we tested rear collision to moving car with zero acceleration, rear collision to decelerating car and side collision with a car. The imminent collision with a pedestrian was tested at a speed of 5 km/h.

	Rear window	Number plates	Back lights
surface	30%-60% of entire contour	5-15% of entire contour	5-20 of entire contour
Geometric shape	Cvasi-rectangle	rectangle	Not defined
position	Above plates, upper half of contour	Center of contour	Left and right extremities of contour
color	Not defined	White and blach	Red

Fig. 10. *Description of the rear of the car*

	windows	wheels
surface	30%-60% of entire contour	5-15% of entire contour
Geometric shape	Cvasi-rectangle	Cvasi-circles
position	Above wheels, upper half of the contour	Lower extremity of the contour
color	Not defined	Not defined

Fig. 11. *Description of the side of the car*

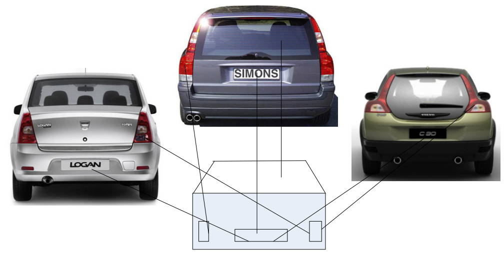
However, in case of bumpy road, dusty car, smoke atmosphere or rain, the system fails to detect obstacles.

	front window	Number plates	Front lights
surface	30%-60% of the entire contour	5-15% of the entire contour	5-20 of the entire contour
Geometric shape	Cvasi-rectangle	rectangle	Not defined
position	Above plates, upper half of contour, above front lights	Center of contour	Left and right extremities of contour
color	Not defined	White and blach	White and/or Yellow

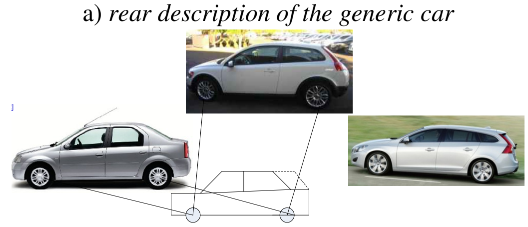
Fig. 12. *Description of the front of the car*

Another disadvantage of the system is that it is not able to recognize other obstacles than vehicles and pedestrians. Several issues need to be solved. How such a system will handle an impeding crash with objects such as fallen trees on the road, big stones is a great challenge.

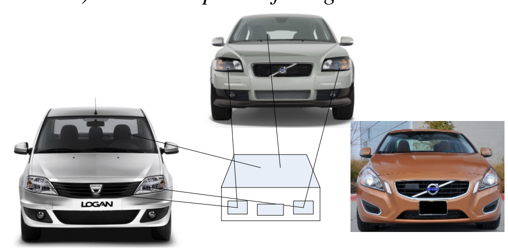
The tests showed good result as the system successfully warned the driver, however there are also failure cases as described below.



a) *rear description of the generic car*



b) *side description of the generic car*



c) *front description of the generic car*

Fig. 13. *The description of obstacle vehicle as the sum of three topological entities: side, front, back is shown in the figure above. Each entities comprises different geometric shapes*

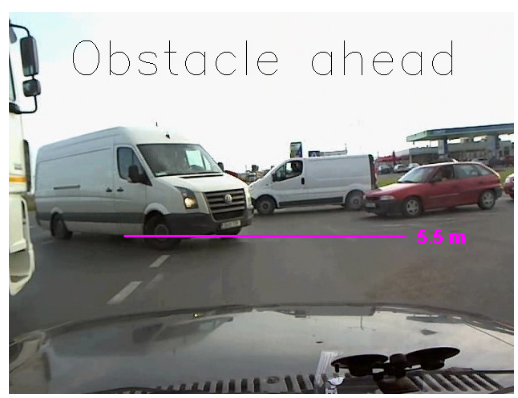


Fig. 14. *Host vehicle approaching another vehicle coming from side road*

Fig. 15. *Host vehicle approaching the stationary vehicle*

Fig. 16. *Host vehicle approaching a pedestrian*

3. Conclusion

This research has successfully developed an integrated vehicle image system in PC-based platform. Based on a single CMOS camera mounted on the windscreen, the system can recognize preceding vehicle, vehicle with side trajectory by proposed algorithms of image processing and provide collision warning functions. The reference inter-distance model permits to analytically calculate the necessary conditions to avoid a collision and provides a suitable brake maneuver to stop the vehicle. Future development will include a 3D reconstruction of the scene ahead of the vehicle. In order to avoid problems such as vision in night, in raining or snowing weather, a solution is the implementation of thermal imaging cameras.

Acknowledgements

The authors gratefully acknowledge the financial support of the Romanian Ministry of Education and Research through grant PN-II-PCE-2008-II ID_791.

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Sistem video de prevenire a coliziunilor bazat pe abordarea topologică

—Rezumat—

Scopul acestei lucrări este de a prezenta un sistem care permite avertizarea conducătorilor auto cu privire la posibilitatea unei coliziuni. Sistemul este compus dintr-o cameră CCD care achiziționează imaginea şoselei şi un calculator pentru procesarea imaginii.

Imaginea de intrare preluată de cameră este utilizată pentru a recunoaşte posibilele obstacole reprezentate de maşini şi pietoni pentru a calcula posibilele traiectorii de coliziune. Ca urmare, sistemul poate avertiza în timp real, prin imagini şi sunete, conducătorul auto astfel încât sa poată fi evitate posibilele pericole.

Metoda propusă este bazată pe detectarea obstacolelor utilizând abordarea topologică.