ISSN 1392 – 1215 ELECTRONICS AND ELECTRICAL ENGINEERING 2011. No. 1(107)
ELEKTRONIKA IR ELEKTROTECHNIKA

T 121 SIGNAL TECHNOLOGY
SIGNALŲ TECHNOLOGIJA

Stereo Vision based Traffic Analysis System

T. Surgailis, A. Valinevičius, D. Eidukas
Department of Electronics engineering, Kaunas University of Technology,
Studentų str. 50, LT-51368 Kaunas, Lithuania, e-mails: tadas.surgailis@gmail.com, algimantas.valinevicius@ktu.lt, danielius.eidukas@ktu.lt

Introduction

Stereo vision system (SVS) is another computer vision version. In this case, view of surrounding environment is analyzed by two video cameras. This system is unique, because observed view can be transformed into 3D image. This 3D image contains more information, so all surrounding environment and objects positions can be analyzed with higher accuracy. Stereo vision has very wide range of applications - starting from robot vision, human control interfaces which can change common uses keyboards or touch screens and ending with cars security and traffic control systems.

Number of cars in the cities and other regions is rising every year. We face with side effects: traffic jams, car accidents in which thousands of people die and many more get injuries. If we look to Lithuanian cars accidents statistic (Fig. 1) we will see, that around 5800 car accidents occur every year. Over 35 % of all accidents happen, because driver hit pedestrian, 10.6 % of drivers hit bike riders, 10.81 % of drivers drive on the obstacle and more than 10 % happen for the other reasons. Only 28 % of all accidents happen by direct car-to-car collisions.

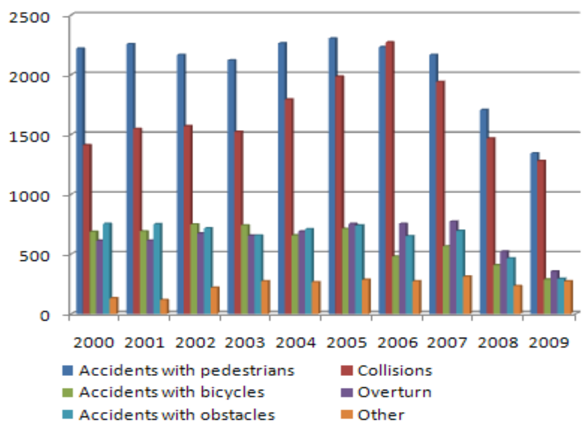

Fig. 1. Car accidents statistic by type, registered during 2001–2009 time period

New technologies can improve safety of car traffic and help to avoid majority of auto accidents or at least reduce that event probability. Intelligent vehicles armed with environment sensors (radar, infrared, ultrasonic), which can analyze covering environment. However, comparing these sensors with stereo vision system they are less flexible. SVS can be the main or secondary part of intelligent vehicle. The main task of this system is to detect obstacles on the road and inform driver or to do certain steps to avoid them. Intelligent vehicles can follow road line, detect obstacles or pedestrians, recognize road signs and follow adjacent cars, or be autonomous [1–7].

Sensors and systems for environment analysis

To avoid unexpected events on the road all surrounding environment around vehicle must be constantly analyzed. It can be done by using environment sensors or analysis system. Changes of environment can be very fast, so system reaction time must be very short. Currently, few types of environment sensors are used mostly: radar, laser, ultrasonic and image processing. Different sensor technology characterizes different sensor features. Main types and features are presented in the table 1.

Table 1. Comparison of environmental sensors features

Feature	Environmental analysis sensors			
	Laser	Radar	2D image processing	Stereo vision
Format	2D, 3D	1D	2D	3D
Distance	~120 m	~200 m	~ 400 m	~400 m
Flexibility	Medium	Low	High	Highest
Hardiness for environment changes	Height	Highest	Low	Low
Price	Highest	Low	Medium	Medium

Output format shows ability of the sensor how thoroughly it can analyze environment. Usually it determines and amount of output data. Sensitive distance shows operating limits. Flexibility feature determines sensor usability. Same sensor can be used for different tasks. Hardiness for environment changes shows sensor ability work in different environment conditions. To ensure any system flexibility and increase the safety often few types of those sensors must be used.

Laser sensors. Laser based environment scanning sensors more known as *Light Detection And Ranging or LiDAR* are mostly used by developers of autonomous vehicles. Even some car manufactures started to install them into new luxurious class car models. LiDAR sensors are very effective, because output of data format is 3D image. This sensor can scan surrounding environment with full 360^{o} angle. LiDAR is an optical remote sensing technology that measures properties of scattered light to find range or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. LiDAR scanning range normally is around 120m and accuracy is few centimeters. But often they are used for short distance environment analysis. It is very important scanning speed, which can achieve 50 times/s. It depends on scanner accuracy and resolution. Often from one to four or more can be used in one vehicle. It is determined by sensor angle scan range. The biggest drawback of LiDAR sensors is price and mechanical technology (rotating parts).

Radar sensors. Radar sensors appeared a little bit earlier then LiDARs. They widely used in cars with intelligent cruise control for at front vehicle speed tracking. Radars work in short and long distances, which can reach few hundred meters. Accuracy of distance measuring is very height and it can achieve from few millimeters to few centimeters. Resolution of radar is very poor. It is only one point per sensor. So mostly, vehicle can have several of them. This is disadvantage, because price of system increasing proportional of sensor count. In addition, system structure gets more complex. Flexibility of radar sensor it is not very height, because only distance can be measured to the object. It is difficult to calculate object motion vector. Therefore, main advantage of this sensor is resistance for environments changes. It well works in day or night time, when is raining, snowing or sun shining.

Ultrasonic sensors. Ultrasonic distance sensors are use very often too. Mostly, you can see them using as parking sensors, installed into car bumper. The principle is very similar like radar, but has more drawbacks: low resolution, more sensitive to environment changes. Variation of environment status (fog, rain, snow, dust) can invoke system failures. Nominal length of distance measurement is around 10 m. Measuring accuracy can be few millimeters, but often it depends on sensor price.

Image sensors. Image sensor or more correctly video processing system is most innovative technology used in intelligent vehicles for traffic analysis. The system consisted of two main parts: image sensor and processing unit - computer or embedded system (Fig. 2). This typical system is predecessor of stereo vision. Object recognition it is very complex task and requires a lot of computer resources. Video processing is very flexible and can process few tasks, but has big drawback. It is very sensitive to environment changes: snow, rain and lighting. For that reason, system needs additional adapting filters, but it requires more calculation resources and reduces calculation speed. These typical video processing systems mostly use for road line tracking [8] or road signs recognition. Working with laser or radar sensors, system can identify detected object.

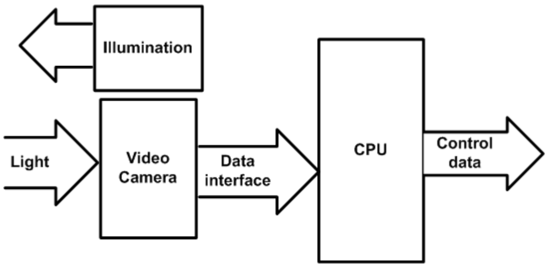

Fig. 2. Typical structure of image processing system

GPS. Global position system became casual device in all latter-days cars. It is important, because it provides reliable positioning, navigation, and timing services. We can calculate motion speed and direction. Accuracy of distance calculation can achieve few centimeters.

Accelerometers and gyroscopes. Other type of sensors is accelerometers and gyroscopes. They are mostly used for local orientation detection. They can measure tilt angle, acceleration of motion or detect impacts.

Stereovision system

Stereovision is one of the main technologies for future techniques, from mobile robots to intelligent vehicles. 3D image analysis requires a lot of computer resources, so the main target is to create new better algorithms, which can process 3D information in real time systems. Especially it is important in the vehicles.

Stereovision is extraction of 3D information from 2D digital images, obtained by image sensors. Stereovision system usually has two or more images sensors or video cameras. The image is projected onto 2D sensor plane (Fig. 3).

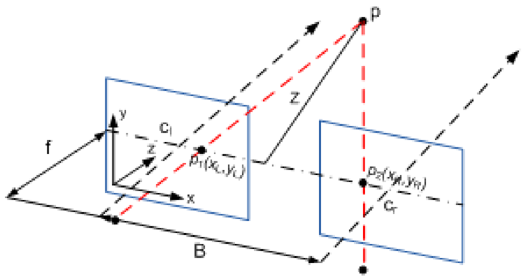

Fig. 3. Typical problem of stereo vision: two image sensors observing an object with different angles

In traditional stereo vision, cameras displaced horizontally from one another are used to obtain differing views on a scene, in a manner similar to human binocular vision (Fig. 3). Enrico Grosso and his colleagues made experiments with 3D images reconstruction based on stereo vision [9]. Over the year were suggested many algorithms for appropriate points detection from two images. Basics methods use absolute or squared pixel intensity disparity [10]. This method is fast. Other methods use window-based matching for better accuracy. There cost function is evaluated around the pixel to find best match. These methods usually do not consider occlusions and present problems in regions displaying little or repetitive textures, leading to similar cost functions and being unable to find the proper match. Calculation speed is most important property. There is algorithm, which does not have mentioned drawbacks. This method can calculate disparity map in real time and was developed for embedded systems, in this case for field-programmable gate array (FPGA) [11].

When disparity map is already formed second step is to find distance for all founded points and to make distance map. Distance can be calculated if the exact position of cameras and distances regarding each other is known. So if we know camera's focal depth ***f***, distance between two optical centers ***B*** and disparity value in left and right images, we can calculate distance to observing point with following expression

$$Z = \frac{f \cdot B}{x_r - x_l}. \qquad (1)$$

Every found point will be calculated with this expression. Finally we will have distance map, which is 3D image information. Afterwards this information will be used for detailed analysis to find and identify objects. These objects can be classified or even be tracked by adapting methods.

This type of vision system is pretty simple, but construction must be very strict, because accuracy depends on it. Image sensors must be with the same alignment and do not change it position over the time. In practice it is impossible, because always exist producing errors and every sensor can be made little be different during production (Fig. 4). Other case, during long time environment can force sensor and system can get out of tune. So system must be recalibrated periodically.

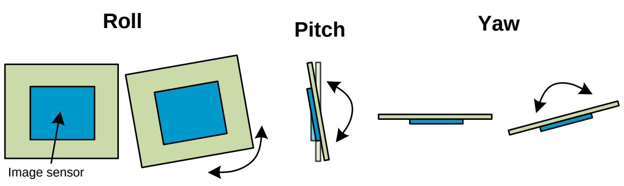

Fig. 4. Image sensors alignment errors appeared during production period. These construction errors can reduce system accuracy

Stereovision system for intelligent vehicle

Integration of stereovision system into vehicle can help to avoid a lot of dangerous situations, which occurs driving a car. The main purpose of this system is to analyze surrounding environment and alert driver about emergency situations or make action to avoid potential obstacle. Stereovision system can be main either secondary part of all environmental analysis system. In some places and conditions radar and laser sensors could be used more efficiently, so combination of all environmental sensors would be optimal decision. Fig. 5 is presented localization of environmental sensors in intelligent vehicle. Stereovision system takes main part of all environment analysis system and responsible for front view analysis. Stereo vision sensing range depends on camera construction. Measuring distance is proportional to the length between two cameras optical centers. Others sensors - in this case radar, observe back and sides. Stereovision based intelligent vehicle can execute several tasks:

- Front vehicle detection and tracking;
- Tracking of pedestrians or animals;
- Road sign recognition;
- Road lines Tracking;
- Obstacle tracking.

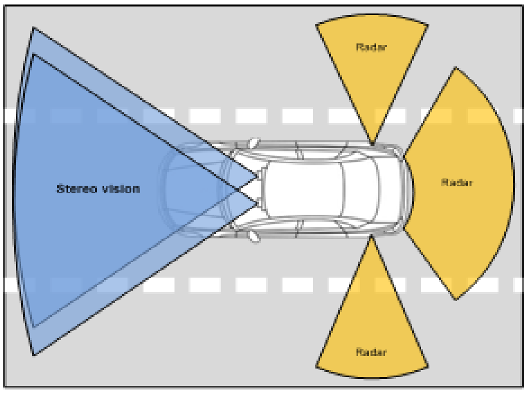

Fig. 5. Intelligent vehicle with environment sensors. Stereovision analyzing front view and radar sensors are responsible for back and sides obstacles detection

Conclusions

Stereovision system for traffic tracking can help driver to avoid unexpected situations, which usually effects vehicle and people. Comparing to other environmental sensors, stereovision is more universal system and more flexible, because it allows to perform more than one task. Technology of image sensors is developed widely, so sensors are pretty cheap and reliable. Image sensors are passive elements, so they do not radiate at all.

Stereovision systems have the big potential and, like usually, some drawbacks. Main drawback is dependence on environment and lighting. This system is very sensitive on environmental changes, for example, daily changes. Special adaptive filters have to be used to overcome this effect.

3D information extraction from 2D images and 3D image analysis needs a lot of computer resources. Development and implementation of new real time algorithms for 3D object extraction and identification is the main current problem.

Reference

1. **Balsys K., Valinevičius A., Eidukas D.** Traffic Flow Detection and Forecasting // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 5(101). – P. 91–94.
2. **Eidukas D., Kalnius R.** Models Quality of Electronics Products // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 2(98). – P. 29–34.
3. **Balaišis P., Eidukas D., Gužauskas R., Valinevičius A.** Modeling of Efficiency of Dynamic Electronic Systems // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 6(86). – P. 55–59.
4. **Balsys K., Valinevičius A., Žilys M.** Crossroads Load Modelling // Proceedings of the 30th international Conference on Information Technology Interfaces (ITI 2008). – Dubrovnik, Croatia, University of Zagreb, 2008. – P. 685–690.
5. **Marma A., Žilys M., Eidukas D., Valinevičius A.** Electronic Parking Control Systems // Electronics and Electrical Engineering. – Kaunas: Technologija, 2007. – No. 8(80). – P. 57–62.
6. **Balsys K., Eidukas D., Marma A., Valinevičius A., Žilys M.** Systems of Transport Route Development // Electronics and Electrical Engineering. - Kaunas: Technologija, 2007. – No. 3(75). – P. 17–22.
7. **Eidukas D., Valinevičius A., Kilius Š., Plėštys R., Vilutis G.** Analysis of Communication channels of the Dwelling Control System // Proceedings of 28th International Conference on Information Technology Interfaces ITI 2006. – June 19–22, 2006, Cavtat/Dubrovnik, Croatia. – P. 513–518.
8. **Risack R., Mohler N., Enkelmann A**. Video–based Lane Keeping Assistant // Proceedings of Intelligent Vehicles Symposium, 2000. – P. 356–361.
9. **Sandini G. E., Tistarelli G.** 3D object reconstruction using stereo and motion // Systems, Man and Cybernetics, IEEE Transactions, 2002. – Vol. 19. – No. 6. – P. 1465–1476.
10. **Sunyoto H., van der Mark W., Gavrila, D. M.** A Comparative Study of Fast Dense Stereo Vision Algorithms // Intelligent Vehicles Symposium, IEEE, 2004. – P. 319 – 324.
11. **Darabiha A., Rose J., MacLean W. J.** Video–Rate Stereo Depth Measurement on Programmable Hardware // IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR '03), 2003. – Vol. 1. – P. 203–210.

Received 2010 09 28

T. Surgailis, A. Valinevičius, D. Eidukas. Stereo Vision based Traffic Analysis System // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 1(107). – P. 15–18.

Provided intelligent vechile concept analyzes status of current traffic. Traffic analyze system based on stero vision technology, wich extracts 3D informaion from observed image. Priciples of typical stero vision system and main problems are described. Possible main functions, which can be used for a intelligent cars to help driver to avoid dangerous situations and incidents are reviewed. Sterovision system features are compared to other types of environmental sensor, which combination can increase system flexibility. Ill. 5, bibl. 11, tabl. 1 (in English; abstracts in English and Lithuanian).

T. Surgailis, A. Valinevičius, D. Eidukas. Transporto srauto analizavimo sistema, grįsta stereofonine rega // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 1(107). – P. 15–18.

Pateikta išmaniojo automobilio, analizuojančio transporto srautą, koncepcija, paremta stereofoninės regos technologija, kai stebimas vaizdas atkuriamas 3D formatu. Aprašomas tipinės stereofoninės regos veikimo principas ir pagrindinės problemos, su kuriomis susiduriama tobulinant šią technologiją. Apžvelgiamos galimos funkcijos, kurios galėtų palengvinti išmaniojo automobilio vairuotojo darbą, bei padėtų išvengti incidentų. Analizuojami ir lyginami kitų tipų aplinkos jutikliai, kurių kompleksinis naudojimas kartu su stereofonine rega gali praplėsti sistemos funkcionalumą ir galimybes. Il. 5, bibl. 11, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).