Carriageway actual parameters determination system development to form virtual road scene in the authentically recognizable road marking absence and negative obstacle presence

A M Groshev¹, S M Groshev², A V Tumasov¹ and A D Romanov¹

¹ Nizhny Novgorod State Technical University named after R. E. Alekseev, Nizhny Novgorod, Russia
² TESA Ltd. Company, Nizhny Novgorod, Russia

E-mail: nil_st@nntu.ru

Abstract. This paper presents the development of the carriageway actual parameters determination system to form a virtual road scene in the authentically recognizable road marking absence and negative obstacles presence. The sensors used in defining the vehicle position and the obstacles are given. The developed system will be able to function independently and also work collaboratively with the other ADAS functions increasing the functional quality of the system.

1. Introduction
The different driver aid systems such as intellectual cruise control systems, automatic parking systems and driver monitoring systems are currently implemented into the vehicle that undoubtedly exert a positive impact on road accident statistics. The video cameras combined with the other sensor types (laser range finders, radars, inertial sensors, the systems of navigation, and etc.) dominate among different touch technologies to provide high reliability (table 1). The development of a new generation of high-speed computer facilities and modern high resolution digital video sensor system employment has allowed making artificial visual devices data closer to human eye characteristics. Table 2 gives the examples of devices to collaborate incoming information during Defense Advanced Research Project Agency (DARPA) Urban Challenge competition. Since hardware opportunities are better, long-term onboard computing capacities now come closer to the human brain computing capacities for processing images [1, 2].

| Table 1. Sensors. |
|-------------------|
| **Type**   | **Data format** | **Features**          |
| Television sensor | 2D - video image | Object shape definition, object environment, high resolution capacity, low cost equipment |
| IK sensor      | 2D - video image | Object shape definition, object environment, a twilight work possibility |
| Type                                   | Data format               | Features                                                                 |
|---------------------------------------|---------------------------|--------------------------------------------------------------------------|
| IK sensor with the illumination system| 2D - video image          | Object shape definition, object environment, a night work possibility, area 3D model creation possibility with the use of the structured illumination |
| Thermovision sensor                   | 2D-thermal video image    | Object shape definition, hot spots quantity and arrangement, object environment, night work possibility |
| Radar                                 | The reflected profile, polarizing images, speed field | Obstacle definition possibility in difficult meteoconditions, including in full zero view in optical and the Infrared range |
| Lidar                                 | 3D – video image          | 3D - form, object arrangement, stage moving sites space distribution, the greatest object detection distance in simple meteoconditions, high resolution capacity |
|                                       | 2D – speed field          |                                                                          |

It should be noted that concrete is used for pavement lying during highway road construction, providing light covering color with poorly allocated white and yellow road marking lines. The lack of difference in gray color shades between pavement and road markings, especially at adverse lighting conditions, isn't enough for unambiguous marking point arrangement in the optical range. The traditional systems are able to recognize a "fresh" road markings at good visibility conditions; nevertheless the damaged marking or its absence (typical for regions) limits the system functionality.

Table 2. Road line detection (examples).

| Make of a car | Stanly | GM | KAT-5 | Sandstorm | Google | Nvidia Car | Tesla | VW |
|---------------|--------|----|-------|-----------|--------|------------|-------|----|
| Information obtaining | Lidar | Lidar and radar | Lidar | Lidar | Lidar, radar and video camera | Video camera | Video camera and radar | Video camera and radar |
| Road marking detection | – | + | – | – | + | + | + | + |
| Partially erased marking recognition | – | + | – | – | n/a | n/a | + | + |
| Carriageway recognition | – | + | + | + | + | – | – | – |
| w/o marking Night movement | + | + | + | + | + | + | + | + |

Table 2 contains examples when component part prices exceed car prices. The use of cheap and available devices (video cameras, range-finders and thermovision cameras) becomes nowadays a key factor for civil vehicles when there are assembly cost restrictions. Object recognition issues are connected to auxiliary but extremely important algorithm training technological issues using real and model data. High quality target detection and target recognition rates can't be achieved without the training.

It should be noted that such phenomenon as road holes (negative obstacles) are well known to all car owners; the road holes have no constant sizes and specific locations on the road. Hitting a hole is always unpleasant and it can become the reason of a breakdown or an accident. To recognize negative obstacles.
Ford Company developed the road holes availability / other road roughness driver warning system. The system represents a digital map on those holes and other roughnesses will be marked at real time. The satellite navigation system with double-sided communication is in its core. Passing a certain road area having pavement defects, onboard electronics and sensor read out of roughness characteristics by means of measuring wheel forces and transfer the processed information to a cloud service. Other cars download the information from the cloud server and display it on the on-board computer screen.

GOOGLE Company’s system is arranged similarly. It is based on the vertical accelerometer. The main advantage of the system is driver notification about invisible holes during bad weather conditions (under snow or water layer). Undoubted advantage of the system is availability of the information to cars not equipped with the obstacle detection system. The main disadvantage of the system is that the information on obstacles is transferred certain time after the first car has already collided with an obstacle and is useful only to other cars. Obstacle definition accuracy is limited with the vehicle coordinates determination accuracy. The system information isn't of any value for the first driver hitting the open hatch.

Besides global positioning satellite signals aren’t available everywhere. Even if system signals are available, the user can face another problem. Coordinate determination accuracy for civilian receivers is 15 meters, but navigation system carrier geometrical sizes are much smaller than the positioning error.

The purpose of the work is the carriageway actual parameters determination system development to form a virtual road scene in the condition of authentically recognizable road marking absence. In particular it determines carriageway limits when road markings are being absent or damaged; the system draws a virtual road marking using road signs requirements, navigation data, roadside width, and road conditions. The system also detects and emphasizes driver attention on small-sized obstacles in a way of the movement, especially on negative obstacles (an open hatch, a hole, etc.).

An integrated approach to interconnected technical sight system component interaction allows implementing new decisions in roadside detecting using additional structured illumination.

The system includes several sensors and is able to adapt under specific operation conditions, including virtual route laying possibility under road network absence (permafrost, steppes, etc.).

Information shown in the table 3 is displayed onto the dashboard or windshield after being collected, processed and analyzed.

| Type                              | Features                                                                                                                                 |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Driving lane                      | Along a driving lane two green strips are highlighted. In case of forbidding marking detection the border is highlighted in red color        |
| Negative or small-sized obstacle  | The obstacle is allocated in a red rectangle and the obstacle symbol is removed                                                         |
| The distance to an obstacle in a  | The obstacle is allocated in a red rectangle and the distance is specified below                                                        |
| driving lane                      |                                                                                                                                 |
| Emphasis attention on the remote  | The obstacle found at a distant area and posing potential hazard is brought onto the separate screen in "zoom"                           |
| obstacle found by the radar       |                                                                                                                                 |

2. Principle of operation

*Road Vehicle Position Assessment algorithm* by means of optical sensors is based on image processing algorithms. These algorithms allow allocating carriageway borders on the image accepted by the observation system using this information to solve an observation system external orientation problem. The road marking lines allocation algorithm is developed within the event image analysis offered earlier [4]. The technical sight system consists of minimum two optical-electronic sensors providing binocular technical sight; is established on the vehicle; and is oriented toward driving direction. At different time points working scene image stereo pairs are formed, identical objects are allocated on images and their three-dimensional coordinates are measured. Object movement trajectories in a shot are determined by each object coordinates. If any object movement trajectory crosses a vehicle movement trajectory, the
warning signal forms. Sensor optical axes are oriented under equal angles \((\alpha/2)\) normally to the axis of the vehicle movement. The sensor arrangement provides the enhanced object space coordinates measurement accuracy at the increased base expense and smaller minimum working distance because of the main optical axes orientation at an angle to each other.

Obstacle Detection on the Plane algorithm described in [5] (a way of three-dimensional object detection on rather smooth surface) bases on the "differential orthophoto" method. Stereo pair left and right images are orthogonally projected onto the auxiliary (horizontal) plane taking into account spreading surface analytical model. Object availability leads to deviation appearance from the surface model. Therefore an object is "projected" on the area blocked by it. There are specific angular brightness and geometrical structures due to the difference between stereosystem camera positions on the left and right orthophoto difference (a differential orthophoto) in the object border field. Thus, the object detection problem can be reduced to simpler to the search of angular two-dimensional structure on a differential orthophoto.

Infrared Range Obstacles and Road Marking detection algorithm is completely developed by the authors. In modern computer and in particular technical sight systems the main role is played by lighting. Creation of a uniform luminous flux on all video camera vision fields in the absence of light patches on controlled objects is a separate difficult scientific and technical task.

Currently rather realistic images of any specific area, including all necessary infrastructure facilities in the visible range waves can be made by means of computer simulating. Unfortunately, the software allowing carrying out high-quality and naturalistic modeling of images in the other ranges is practically absent or is extremely inaccessible in the market.

Obstacle detection using infrared range sensors, both with illumination and without it generally is similar to optical range sensor detection. The essential difference of the system is ability to work with the small-sized, negative obstacles and also with roadsides detected with the use of the structured illumination [6 - 8]. There is an analysis of an illuminated image part and the hypothesis of its geometrical sizes is checked. The use of the specialized structured illumination allows significantly simplifying and reducing the cost of all system generally.

The thermal image helps to find road limits to detect coming turns earlier, etc. Thermal Range Obstacles detection algorithm based on road infrastructure specific elements identification to have different temperatures and on optical range sensors analysis simultaneously. The performance check is necessary as in some cases where there is a shadow from a foreign object on a vehicle driving lane that actually isn't on a driving lane (figure 1) leading to a collision warning system false drop.

![Figure 1. The road and a tree shadow (thermovision and optical ranges).](image-url)
Figures 1 – 3 show the photographs of roads sections in the thermovision and optical ranges. Measurements were made in non-optimal days for thermal imager (summer, afternoon, + 30°C air temperature, + 42°C road surface temperature) [7 - 8]. The specific road elements were found. At night pavement detection is possible due to different heat capacity of an asphalt/concrete surfacing and the surrounding areas. Optimum conditions are provided right after the sunset (the most dangerous period) when the driver hasn’t yet adapted to new night traffic conditions.

Detection of large obstacles such as vehicles is based on detecting specific car elements (figure 1), especially a radiator or the exhaust system (at a foreshortening 0/4) and wheel naves (at a foreshortening 4/4). If there is any uncharacteristic thermal anomaly detecting (a hot spot) in a driving lane or moving in the direction of a driving lane the system warns the driver and helps him to avoid collision with people and animals coming out onto the unlighted carriageways at night.

Detecting negative obstacles (figure 4), thermal road surfaces fields, with abnormal temperatures are evaluated.
The algorithms mentioned in the paper supplement such distance measurement subsystems as "radar" and "lidar" and are used as auxiliary elements in normal weather conditions to measure the distance to the objects already found.

The radar becomes the main obstacle detection system during poor conditions (rain, snowfall, fog, etc.). Optical, IK and thermal range systems help to define and recognize targets at the shortest distance. The main principle is "we don't see an obstacle, but we know it is and are ready to classify it".

Acknowledgements
The research has been done with the financial support of small form scientific and technical sphere enterprise development assistance fund (Innovation Assistance Fund).

References
[1] Zheltov S Yu and Wisilter Yu V 2009 Perspectives of intellectualization of control systems of aircraft due to application of computer vision technology MIPT 1 (4) pp 164 - 181
[2] Visilter Yu V, Vishnyakov B V, Vygolov O V, Gorbatevich V S and Knyaz V A 2016 Intelligent Information Processing Technologies for Navigation and Control Problems of Unmanned Aerial Vehicles SPIIRAS Proc. 2 (45) pp 26 - 44
[3] Visilter Yu, Zheltov S and Stepanov A 1996 Events-based Image Analysis for Machine Vision and Digital Photogrammetry SPIE Proc. International Archives of Photogrammetry and Remote Sensing 31 p 5
[4] Zheltov S Yu, Sybiryakov A V and Vygolov O V 2002 Car collision avoidance system based on orthophoto transformation Intern. Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences (Greece) 34 pp 125-130
[5] Xin L, Wenguang H and Haoiang S 2008 The Theory and Application of Structured Light Photogrammetry with Known Angle XXIst ISPRS Congress Technical Commission pp 101-106
[6] Lanman D, Crispell D and Taubin G 2009 Surround structured lighting: 3-D scanning with orthogonal illumination Computer Vision and Image Understanding 113 (11) pp 1107-17
[7] Tarasov V V and Yakushenko V G 2004 Infrared systems of the looking type (Moscow: Logos) p 443
[8] Gosorg G 1988 Infrared thermography. Fundamentals, technique, application (Moscow: Mir) p 399