The concept of using computer vision in control of autonomous transport

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Abstract. The paper discusses technologies of control over unmanned self-propelling transportation vehicles in enclosed industrial areas based on computer vision with active adjustable mapping of the vehicle motion path. The authors describe substitution of LIDAR sensor for a light net mapped on the road surface.

1. Introduction
Self-driving vehicles are no more science fiction but the ordinary high-technology equipment within enclosed mine areas in the world. In the mean time, major load yet falls at the common manned machines. Such situation is caused by many reasons, starting from imperfection of regulatory and legal framework and finishing with financial matter. The regulatory and legal framework for the unmanned transport use in Russia will be lively developed in years to come, apparently. Thus, the issue of the day is to work out a simple and readily set up technology of control over autonomous transport.

One of the objective drawbacks of self-driving vehicles is certainly the cost. It is a critical task to reduce the cost of a transportation vehicle at the minimum loss in its efficiency. With this end in view, it is important to understand which elements of an independent control chiefly increment the cost and how they are substitutable. As of today, any self-driving vehicle necessarily has a unit to scan the area in front of it. Among various types of such units, the most popular sensor is 3D-LIDAR because of its high accuracy. 3D-LIDAR sensor creates a point cloud to shape a 3D pattern of what is taking place in front of a vehicle. This 3D pattern is readily translated into the plain language for the control system to correlate the distance to certain points in the cloud with the control function (retargeting, deceleration, acceleration, etc.). An open road situation can change within a few seconds, and lives may depend on the electronic driver response [1]. In the same time no people or others vehicles should be present on a special industrial site, and the road situation is then more static and predictable. Accordingly, no fast-response facilities are required to sense the road situation in front of a transportation vehicle. However, the cost of equipping an unmanned transportation vehicle with high-quality 3D-LIDAR easily goes over tens of thousands of dollars. In the meanwhile, some heavy trucks may need two sensors in certain conditions.

2. Methodology
An obvious question on possible alternatives to 3D-LIDAR arises. At the modern development stage, it is difficult to substitute a LIDAR sensor for a single cheaper device. The objective is achievable through integration of a number of technologies. According to the authors, the main alternative to a LIDAR sensor is a high-resolution video camera connected to a large-powered computer for video
processing—a computer vision system. Unfortunately, robots cannot see like humans, and it is impossible to entrust a computer vision system to drive a heavy-duty truck without additional equipment. The reason is that it is yet very difficult to detect road irregularities and motion interference on a video image. It is necessary to have a marker to assist to distinguish road inequalities and obstructions in the general visual environment, and to determine its size and position.

The Laboratory of Coal Mining Machinery in Federal Research Center of Coal and Coal Chemistry, SB RAS has been investigating computer vision technologies and prototype hardware/software control systems based on the change of shape of light markers. One of such prototypes is a self-driving transportation vehicle with computer vision control (figure 1).

Figure 1. A prototype self-driving transportation vehicle with computer vision control.

3. Results and discussion
The computer vision system process flow includes: pre-processing of video signal, segmentation, identification of geometrical structure and determination of relative structure and semantics [2].

Efficient operation of computer vision needs simplifying to the maximum extent the pre-processing stage [3]. To this effect, it is suggested to introduce surface illumination in front of a vehicle using a net of contrast-color straight-line light markers. In this case, everything undue is removed from the scene at the stage of pre-processing, and the further stages of imaging become greatly simplified, for instance, such elements as a point, a straight line or an angle are already detectable [4]. For illustration purposes, figure 2 demonstrates the image processed at the Laboratory.

Figure 2. Results of processing of image with light markers.
Moreover, when the line-shaped light marker intersects an obstruction of traffic, the line loses its straightness (figure 3). With known arrangement of the net relative to the vehicle, the computer vision system defines fast and precise the type of a obstruction (a dimple or a bump), or the road grade. After debugging, the system will identify popping-in objects comparable in their size with the size of the cells created by the light markers. The shape change of the marker will help the computer vision system to trace more precisely the road slope, turns and track ruts.

The use of a similar technology offers an opportunity to create a navigation system for travel of an unmanned transportation vehicle in an industrial area without assistance of satellite navigation. The prototype navigation plotting method is used at the robot-manned production plants and in the industry of sports robots [5]—movement of a robot along a contrast line drawn on the surface (line following). Evidently, it is impossible to draw a contrast line on a road in a surface or underground mine. It is proposed to use a contrast light guiding marker in this case. The system with illuminated guiding markers can be arranged on the poles, walls, piles or slopes along the route of a heavy-duty transportation vehicle. The transportation vehicle will cyclically follow this route unless a new command is received. A complimentary advantageous option of such system is modification of the route by the mine management independently. To this end, a new ‘light road’ is laid in an assigned place and is connected with points of autonomous loading and unloading.

![Figure 3](image.png)

**Figure 3.** Identification of road blocker by broken straight-line light marker.

Similarly, the task of a dump truck placement for loading or unloading is solved. At the entry to the loading/unloading area, the gates are installed, which send a signal to the control system to stop the truck and to wait for a signal to move. The loading operator decides on loading the next truck and
sends a signal to the central control to position a shovel relative to the entry gate where the unmanned vehicle is awaiting. Then, the operator assigns the convenient point for the vehicle placement for loading in the control system. Based on the information on the position of the loading machine, computer models the path of the unmanned vehicle motion. This path is converted to the coordinates of position of suspension axes by emitters of light markers in order to shape a light marker for the dump truck to take its place in the loading area. The outlet path is modeled in the same manner.

4. Conclusion
Integration of the computer vision system and light markers allows a system of unmanned control over heavy-duty transportation vehicles in an industrial area at the much lower cost as compared with the LIDAR-based system. The complimentary benefit of the new approach is the option of transfer of the vehicle to another site, or the change of the current route without on-board computer re-programming.

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