3D laser scanning for monitoring the quality of surface in agricultural sector

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Abstract. The paper considers three technologies for obtaining data on the road surface - through video recording, thermal imaging and laser scanning for the purpose of monitoring, diagnostics and control of the road quality. An analysis of the first two methods showed their significant drawbacks, such as the inability to measure the geometric parameters of deformations (video recording) and the significant dependence of the measurement results on external conditions (thermal imaging). Laser scanning, on the contrary, has a number of advantages, including coordinate referencing, obtaining a three-dimensional model, its transformation and measurement of parameters. Laser scanning is widely used, but mainly for measuring the quantitative characteristics of objects. The paper discusses the application of the laser scanning method to determine the qualitative characteristics of the road surface - the presence or absence of defects, which include hollow spots, waves, cavities, chipping, bleeding, humps, cracks, vertical displacement of road plates, rutting, unevenness of patching, damage to the road surface, track, breach, destruction of the pavement edge, subsidence followed by a complex of repair work. For this, a ground-based laser scanning was performed, the results of which were processed using the Leica Cyclone 9.4 software. According to the scanning data, defects were detected in the form of soil subsidence, hollow spots and humps. The performed work revealed a drawback of the laser scanning method, which consists in the absence of automated detection and recognition of deformations. A number of measures have been proposed to improve this drawback, which slows down the randomness and quality of work in monitoring and diagnosing the road. Further prospects for research on this topic, in particular the multi-purpose use of scanning data, by creating a distributed ledger are also indicated.

1. Introduction

Motor roads are a complex dynamic system through which a large number of road users at risk travel daily.

According to the Federal State Statistics Service (Rosstat), the number of deaths in road accidents amounted to 12.4 people per 100 thousand people in 2018. In the total population of the Russian Federation of 146 510 064 people, the scale of deaths is 18 167 citizens.

To reduce and prevent traffic accidents, the national project “Safe and high-quality roads” was launched in 2018, the financing of which is 106.2000 billion rubles in 2019, in 2020 – 116.7020 billion rubles, in 2021 – 180.4020 billion rubles.
Such a vector of politics on the part of the state is objective, because it is quality roads that are the key to social security, protection of health and lives of citizens. In this regard, it is extremely important to pay attention to the implementation of road safety and quality control, using modern technologies, which are discussed in the paper.

Road safety largely depends on the quality of its design, compliance with construction technology and compliance with all regulatory and technical requirements.

It is also possible to ensure the safety of citizens on the road in the case of regular monitoring of its condition for various deformations of the road surface, which include hollow spots, waves, cavities, chipping, bleeding, humps, cracks, vertical displacement of road plates, rutting, unevenness of patching, damage to the road surface, track, breach, destruction of the pavement edge, subsidence followed by a complex of repair work.

Nowadays, the work on the diagnosis of the geometric dimensions of deformations is carried out by means of a manual system using a three-meter rail with a wedge-shaped meter, a metal ruler or measure tape, as well as a device for measuring distance with an error in measuring distances of not more than 10 cm.

Such an imperfection affects a large number of scientific papers, which show promising methods for monitoring the quality of the road surface. For example, the authors Nguyen Thu Hyong, Nguyen The Long [1], Menshikov A.M., Skomorokhova N.A. [2], and Rosdortech and “Road-PRO” agencies suggest using a video camera to record the deformation, the authors Melnikova I.S., Daineko K.N. [3] - thermal imager, Sobol B.V. [4], Marcin Staniek, Piotr Czech [5] - a highly accurate neural network, and the authors A. V. Seredovich, A. V. Ivanov, V. A. Seredovich, Maysuradze Sh.G., Maysuradze I.G. [6], M. Slabej, L. Podolka, M. Grinč, J. Musilek, J. Čejka [7], T. Vondráčková, P. Kotek [8] - laser scanning data.

An analysis of domestic and foreign literature showed that there are variations in the application of laser scanning methods, but they are not sufficiently developed or there is lack of data processing technologies and methods, in particular, for the automated determination of the geometric parameters of surface defects, which has a decisive role in calculating the necessary materials for their elimination. Also, the issues of identification and data processing in the event of external disturbances, which include garbage, shadows, markings, the remains of the old road markings, are not sufficiently considered.

The existing gaps in the technological solution of the problem of diagnosing the quality of the road surface in the context of road safety determine the purpose of the study - to automate the processes of diagnosing road surface deformations, monitoring the condition of existing roads, and controlling the compliance of the quality of newly constructed roads with regulatory and technical requirements using laser scanning technology, taking into account automated data processing methods.

The main terms encountered in the paper are:
1. Road damage - defects in the road surface, which are hollow spots, waves, cavities, chipping, bleeding, humps, cracks, vertical displacement of road plates, rutting, unevenness of patching, damage to the road surface, track, breach, destruction of the pavement edge, subsidence;
2. Point cloud - a set of points with three-dimensional coordinates, designed to represent the surface of an object, its model;
3. Computer vision - a technology for obtaining, processing and using images of real objects without partial or full human involvement.
4. Distributed ledger - a decentralized database that allows the simultaneous storage of copies of ledger data and their automatic update at the same time for all its users.

2. Methods
The paper is based on the materials of ground-based laser scanning performed in the summer of 2019 in Krasnodar using the impulse scanner shown in Figure 1.
The device has a two-axis compensator, a full field of view (horizontal 360, vertical 270), a built-in video camera and a laser plummet [9]. The scanner allows measuring up to 50,000 points per second, while the accuracy of measuring a single location is 6 mm, and the distances are 4 mm, the vertical and horizontal angles are 12′′/12′′. The discreteness value was set to 10*10 cm.

A laser scanner measures the distance from the scanner to the road surface with high speed and registers vertical and horizontal angles with the subsequent formation of a three-dimensional image (scan) in the form of a point cloud [10,11]. For each such point, three coordinates (XYZ) and a numerical indicator of the intensity of the reflected signal, which is determined by the properties of the surface on which the laser beam is incident, are recorded during the survey [12].

The technology of field measurements included the following steps:

1. reconnaissance of the area of work (to select the points of geodetic control (survey points), reference benchmarks, scanner position);
2. development of the geodetic control (the coordinates were determined using GPS in the "Static" mode);
3. installation of the scanner at the designed point: centering;
4. arrangement of special reference benchmarks around the scanner, determination of the coordinates and the heights of their centers (using a total station from survey points);
5. ground laser scanning;
6. moving the device to the next scanning point and repeating steps 3-6.

Processing of the scanning results was performed in the Leica Cyclone 9.4 software product in the following order:

- Import of data (scan, photo, benchmarks) of each station into the program;
- Registration of the project;
- Stitching point clouds by benchmarks.
- Obtaining a general model, a fragment of which is shown in Figure 2.
The primary image does not clearly reflect the deformation of the surface. For a better visual representation, it is possible in this program to color the points by benchmarks, color intensity and in real colors. The latter is possible due to the existing built-in video camera [11]. Figure 3 shows a road whose point cloud was colored from blue to red in accordance with benchmarks.

Based on this image, deformation measurements were taken, the functions and capabilities of existing software were considered, and the possibility of using laser scanning data to diagnose other damage was analyzed.
3. Results
When diagnosing road surface deformations, monitoring the condition of existing roads and controlling their quality, two main issues need to be addressed: with what instrument will the data be obtained? And how can it be processed to search for defects in the roadway?

Data collection can be carried out in contact and remotely. The first is the direct measurement of deformation parameters, at which cutting and drilling of the road surface is possible for the subsequent study of the physicochemical composition in laboratory conditions [13]. Remote obtaining of information can be done by surveying with a video camera, stereo camera, thermal imager, laser scanner.

Diagnosis of the condition of the road surface using the data of the video camera is carried out by installing it on a car, during the movement of which the road surface in the studied area is sequentially recorded.

Recently, this method is the most common and finds its application in mobile road laboratories in connection with the efficiency and visibility of information. However, when using video as the only data source, there are a number of disadvantages:
- insufficient contrast of the video image, which does not allow recording small cracks, tracing the initial stage of surface deformation;
- the dependence of the degree of detail on the car speed (recognition of defects with a size of less than 1 mm) can be obtained with a speed limit of 50 km/h;
- lack of accurate coordinate reference;
- inability to perform measurements;
- subjective pattern recognition at the processing stage.

The thermal imager is also mounted on the car. However, the principle of the device’s operation is based on recording infrared radiation with subsequent transition of the data into the visible spectrum in the form of a thermogram. The detection of surface defects occurs due to differences in the temperature of a flat surface and a defective region and, as a result, differences in the emissivity of the surface of the test object [13].

Compared to the previous one, this method allows revealing cracks at an early stage of their occurrence with an opening width of 1 ... 2 mm. However, this is possible under a number of conditions:
- it is necessary to ensure the selection of lighting angles and observation of the spectrum and intensity of the source, as well as the state of polarization and coherence of light to ensure maximum contrast of the defect [3].
- it is necessary to take into account the emissivity of the measurement object, relative humidity, ambient air temperature, distance to the object, the reflected temperature of third-party objects [3].
- measurements are taken in the warm season in the evening after sunset. Under these conditions, the influence of solar radiation is excluded, the surface of the pavement has already begun to cool naturally, and the area with the defect still remains well warmed up [3].

Such a dependence on external conditions allows making conclusion about potential gross errors in the measurements.

The use of laser scanning has several advantages relative to the above methods [14]:
- binding the collected data to the coordinates of global positioning, which will quickly and efficiently determine the exact location of the defect
- surveying at temperatures from 0 °C to 40 °C
- full performance in absolute darkness and in bright sunlight
- obtaining a three-dimensional image of deformations.

However, a significant drawback of the method is manual diagnosis and processing of measurement results.

General deformation diagnostics was carried out on the basis of a profile, a detailed fragment of which in several planes is shown in the figure 4.
The profile has a hollow spot (local destruction of the pavement, having the form of a hole with sharply defined edges), a hump (local deformation, having the form of a smooth elevation of the pavement without destroying the pavement material), and also soil subsidence (deformation of pavement, having the form of a hole with a smooth outlined edge, without destroying the pavement material).

Measurement of the width and deformation length was carried out by measuring the distances from the extreme points of pavement damages. Depth can be determined by the difference between the marks of the lower and upper points of the defect or by the road profile. So, the width of the hollow spot was 1.0569 m, the width was 0.4439 m, and the depth was 0.36 m.
The detection and study of small defects (crack, network of cracks) is possible with a decrease in the discreteness value, which will increase the density of the point cloud, and with an increase in the scanning step.

Carrying out manual diagnostics and parameterization of defects on a scale of the total length of the road significantly reduces productivity, quality of work and comprise the main disadvantage of using laser scanning data. For exclusion, it is proposed to develop a methodology and technology for automating data processing processes, as a result of which the search and calculation of deformation parameters will be performed using computer vision. This can be achieved by developing methods of filtering, image segmentation, pattern recognition, as well as the application of artificial intelligence technology.

4. Discussion

The introduction of a laser scanning method for diagnostics of the road network, controlling the quality of the pavement will allow for quick and mobile data collection, and the introduction of automated processing methods for automatically recognizing and recording damage to the pavement will speed up the process of finding defects, automate the calculation of the necessary materials for restoration of the roadway.

Such a modern monitoring system will provide high-quality diagnostics, timely repair of the pavement, will prevent serious damage, subsidence of the pavement, will bring it closer to the concept of safe and high-quality roads, which is directly related to the life and health of citizens.

5. Conclusions

Future studies are aimed at developing a technology for automating the processing of laser scanning data, as well as at creating a single accessible information resource with a well-developed system of information interaction between different structures that use the same data for different purposes. For example, the data of laser scanning of roads can be used in the land cadastre to obtain the coordinates of the measured points of the land plot, putting it on cadastral registration, establishing protective zones [15]. It also can be used by municipal, regional, federal bodies for managing infrastructure elements, carrying out work on certification, inventory; by design construction organizations to obtain a topographic basis for future design decisions; by road agencies for diagnostics and quality control of performed repair work, their maintenance level, etc. The implementation of such information mobility is proposed to be implemented through the development of a distributed ledger, which is a decentralized, expanded in accordance with the relational databases experimental system of interagency interaction.

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