COLLECTING, ANALYSIS, CLASSIFICATION METHODS AND APPROACHES OF THE ROAD PAVEMENT DEFECTS DETECTION

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This project considers the problem of identifying and classifying the type of damage to the road surface according to the accelerometer installed on the car. Compared to the existing data analysis methods, such as 3D data analysis or image analysis, this approach looks interesting because it is relatively cheap to implement and does not require expensive industrial cameras and lidars. The idea of the method lies in the fact that when the road surface is damaged, the acceleration of the car changes (for example, when driving through a damaged road, the amplitude of the car's vibrations increases, or there is a sharp change in the acceleration component when the driver tries to around the damaged section of the road). Accordingly, such a change in the accelerometer data can potentially determine the presence and type of deterioration. The main task of the implementation is to create a predictive model that can detect patterns in the accelerometer data that will reliably indicate the presence of damage. This project aims to verify the possibilities and limits of this method on actual measured data.

Key words: accelerometer, gyroscope, road deffect identification, machine learning, data and signal rocessing,

INTRODUCTION

The project touches on accelerometer data analysis. It was decided to take road pavement defect identification and classification issues as a practical task to show the implementation of the theoretical assumptions. Keeping a road surface in good condition is very important for safe driving. The process of pavement monitoring is a highly time-consuming process; it requires special skills and knowledge in the area. Another important aspect of the issue is the necessity to perform periodical monitoring of the surface in order to have an actual representation of the situation. That means that the process should be automated. There are already several methods and solutions based on computer vision technologies. Despite the relatively complex implementation, it works but requires expensive equipment. This research shows the possibility of solving this problem by processing data from the accelerometer, which could be a less expensive alternative to computer vision-based methods.

METHODICS

Road pavement defect detection topic has already been considered in the literature. It is possible to distinguish the following groups of approaches:

- Image analysis, a damage detection approach based on the image processing received from the camera using deep convolutional neural networks [1],
- Vibration data analysis, use of accelerometers or gyroscopes mounted on a vehicle [2],
- 3D data analysis: use of stereo images or LiDAR data for damage detection [3].

The collection of 3D data requires specialized equipment, so this approach can only be used to a limited extent, for example, to verify the results of forecasts or to obtain a markup of measurements collected by a different type of sensor. The main disadvantage of the image analysis approach is the requirement for a large number of images with marked damage. Also, the model for damage detection is quite sensitive to false positives - for example, in some cases, shadows can be classified as certain types of damage. Moreover, it is necessary to perform re-collection of data for the roads in other areas/countries, as computer vision models can often be quite sensitive to changes in the background against which images are taken. The vibration data analysis approach is the most cost-effective, as no relatively expensive sensors are actually required. The problem of detecting damage to the roadway can be considered as the problem of detecting anomalies in time series (accelerometer readings). However, the use of such methods often leads to a significant proportion of false alarms in forecasts, which is unacceptable as well. For this reason, it requires careful preparation of a large number of training data in order to gain the correct output.

The basic idea of the project is that the vehicle's acceleration changes when the road is damaged (for example, the amplitude of the vehicle's vibration increases when passing through a damaged road, or there is a sharp change in the acceleration component when the driver tries to avoid a damaged section of the road). According to this, such a change in data from the accelerometer can potentially detect the presence of damage and its type. This approach is easy to implement in practice. This means that installation of any specialized complicated equipment is not required, and the main difficulty in implementing this approach. It is hard to build a predictive model capable of identifying patterns in the accelerometer data, which will reliably indicate the presence of damage. It is required to carry out test measurements, during which the researcher collects the data from the accelerometers to build a predictive model. In addition, for these measurements, it is required to select the trajectory coordinates corresponding to the positions of damages on the roadway and the corresponding time points at which these damages were encountered (data labeling in the form "damaged/no damage"). It would be possible in this case to calculate the signs that allow detecting damage and, using the provided markup, train the classification model for damage detection according to the accelerometer data presented in the form of time series.

Our idea of data processing in road pavement state monitoring is an application of the Neural Networks. We used Long Short-Term Memory Recurrent Neural Networks (LSTM) and their modifications: CNN-LSTM and ConvLSTM. LSTM network models are a type of Recurrent Neural Network that can effectively learn and retain information over long sequences of input data, making them suitable for hundreds of steps.

Several results of applying the mentioned Neural Networks are shown below in fig. 1. Blue curve – original signal from the accelerometer, red curve – the identified defects. Green windows show the differences in identification for different Neural Networks.

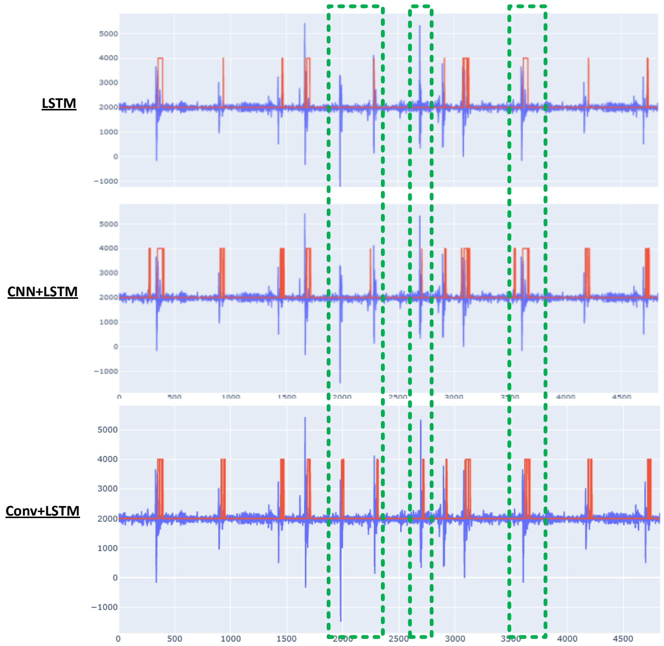

Figure 1: Comparison of the LSTM and modifications

RESULTS AND DISCUSSION

According to the nature of the task, we chose the following metrics to assess the performance:

- Recall - the metric that indicates that the desired defect of the pavement occurs,
- Precision - the metric- the proportion of correct positive combinations among all combinations.

Table 1: Metrics summary

Model	Precision	Recall
LSTM	0.79	0.65
CNN-LSTM	0.67	0.73
ConvLSTM	0.80	0.78

As could be seen from the values in Table 1, CNN-LSTM and ConvLSTM, compared to the basic LSTM, have an 8-11% larger recall value; at the same time, comparing the CNN-LSTM and ConvLSTM, shows that the ConvLSTM has up to a 13% increase in the precision metric.

CONCLUSION

Why were Neural Networks chosen as a possible tool for the task? LSTM and modifications are supposed to be used in more extended meaning. We plan to expand the amount of the defect classes and coect more data. The application of Neural Networks such as LSTM, CNN-LSTM, or ConvLSTM will provide us with this opportunity.

ACKNOWLEDGEMENT

This work was supported by the Student Grant Competition (SGS) project at the Technical University of Liberec in 2023.

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