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Asphalt-surface defects detection, based on tyre/road noise analysis and geo-processing.

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ABSTRACT

A new approach to detect different asphalt defectology based on tyre/road noise analysis by Machine Learning algorithms is proposed. In this way, a probe of concept was carried out to exploit the acoustic signal generated by the tyre-asphalt interaction. The audio data were recorded by an equipped vehicle that had travelled an established route with supervised surface conditions.

The acoustic signal decomposition in frequency domain has shown to be relevant on automatic asphalt-defect classification. In this probe of concept, a group of four local and distributed road-surface defects were automatically detected and plotted on map. As a result, it is possible to visualize the asphalt zones with different superficial defectology.

This new approach does not require a specific on-board instrumentation setup, so any vehicle could easily be an asphalt status tester with the installation of a microphone. The possibility of an interconnected fleet of sensing vehicles to gain robustness in the final report is also described.

Keywords: tyre/road noise, asphalt deterioration, pattern recognition.

1. INTRODUCTION

Roads are essential elements for the economic and social development of a community. Therefore, keeping them operational is a key administrative activity. In this regard, the monitoring and maintenance of the highways facilities might be kept as least driving-restrictive as possible. Traditionally, destructive tests have been applied, however, these methods include core extraction and subsequent analysis.

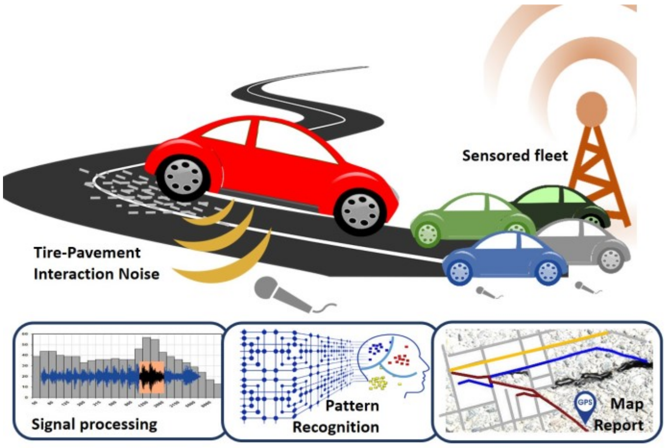

Figure 1. Report of asphalt deterioration by instrumented vehicles

Currently, new non-destructive methods are being implemented for road infrastructure inspection.

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Some of this methods include the analysis of electromagnetic, lasers, images and vibrational data (1–4). Although the above techniques provided optimized results, they did not take advantage of an inherent effect of the rolling phenomena, as tyre/road noise.

The rolling noise generated is closely related to the surfaces conditions of the asphalt and the tyre, therefore and important information is available in a wide frequency range and it becomes clearer with increasing rolling speed (5). Since it might be possible to process this signal to obtain information on the elements involved in this interaction, some previous works have been carried out experiments to relate the acoustic foot-print with: road-materiality type, roughness classification and wet conditions (6–9).

The Figure 1 depicted the probe of concept performed on this work, that is to achieve an exploration of the rolling noise signal in order to identify the surface-damage conditions over a route.

In addition, the classified route segments were geo-processed to show a global mapping report of the actual road conditions. The final map was provided by processing the data recorded at several passes of the sensored-car, traveling under normal traffic conditions.

This raises the practical feasibility that an interconnected fleet registers the tyre/road noise signal from different and/or redundant zones and consequently supply the database to improve the definition of the final map.

2. METHOD

2.1 Route conditions

A road with different zones of superficial road damage-condition was selected. Both continuous and localized defects were deemed. Additionally, one class for new asphalt layer was included for these probe of concept experiment. In this scenario, four categories were established for automatic classification as is depicted in Figure 2. The aforementioned route has some advantageous attributes, as the lowest background noise because the selected route is located within the university UPM facilities, and the low traffic; in the other hand the speed is limited at 30Km/h.

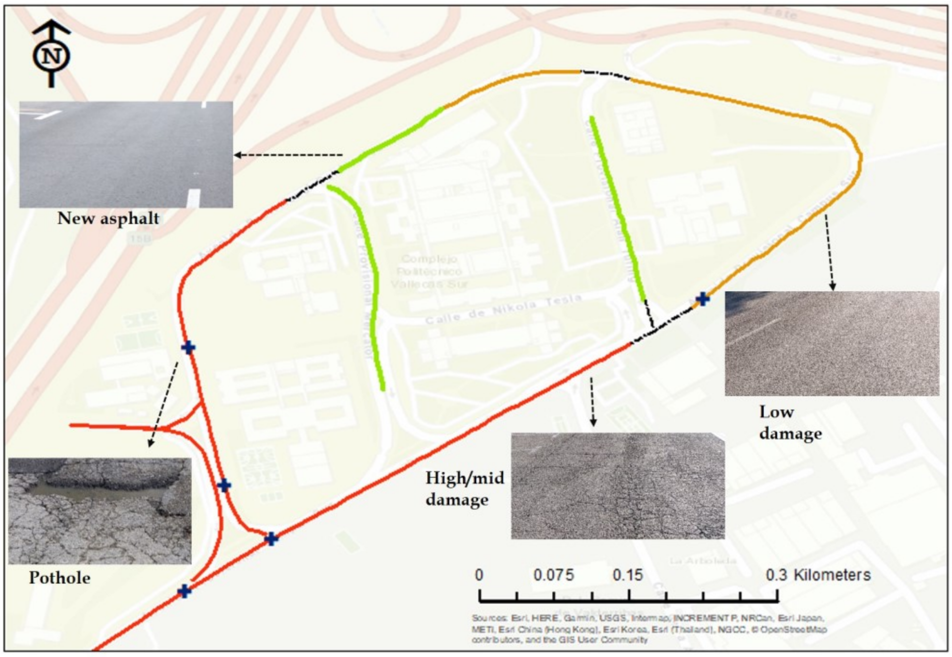

Figure 2. A-priori labeling of route segments.

2.2 Signal Processing

The tyre/road interaction noise was recorded with a calibrated class-1 microphone, connected to data acquisition devise. The sensor was installed at rear-right tyre/pavement proximity zone by OBSP method (10). The signal was sampled at 51 kHz for further wide frequency-range analysis.

In order to use these noise registers in the next pattern recognition tasks, the signals were framed into 100 ms. (without overlapping) and decomposed by 1/3-octave filter banks. This feature extraction approach has provided good results on related audio-based classification tasks(8,9).

Simultaneously at audio recordings, the route was tracked by GPS devise to further mapping of the results.

2.3 Pattern Recognition

A dataset with 23590 instances with 32 frequency and noise level features was performed. Next, a pattern recognition model was implemented by cross-validation (k-fold=5). The Nearest Neighbor (KNN) with (k-neighbors=3) supervised multi-class classifier was the ones with the best performance as is showed in the confusion matrix (Table 1).

The classifier provided strong overall performance metrics: macro F1-score = 0,857 with standard deviation = 0,009. The classification with the best accuracy was "new asphalt" class (99.1%), and the lowest accuracy was obtained at "low damage" class (80.2%). The average accuracy of the obtained model was 92,1%.

Table 1. Confusion Matrix (%) of superficial damage classification

		Classification			
		New asphalt	Mid/high damage	Low damage	Pothole
Actual	New asphalt	99.1	0.5	0.4	0.0
	Mid/high damage	0.0	89.9	9.7	0.4
	Low damage	2.8	17.0	80.2	0.1
	Pothole	0.0	15.4	3.8	80.8

Afterwards, new audio recordings were processed to conform the dataset for automatic classification. Four circuit-laps had been driven for emulate a fleet that traveling the same route. Consequently, the automatic classification of the new data was obtained. The next step is to present these results by means of a mapping report.

3. RESULTS

3.1 Geo-processing

Once the results of the audio-instances classification were obtained, they were matched with the corresponding coordinates of the tracking file, i.e. date-hour records. Figure 3 shows the automatic detection grouped by the colored assigned class for asphalt deterioration, i.e. green: "new", yellow: "low deterioration", red: "mid and high deterioration" and blue for "pothole" event.

The automatic class-recognition of the asphalt-damage above the route is closed related with the a-priory labeled segments depicted in fig Figure 1. Even the zones with instances of a pothole can be recognized. Some superficial elements as bumps or speed reducers contribute on miss classification of the model. This is a problem that needs to be addressed in depth in future research.

Overall, the resulting map provides an important identifier of the expected asphalt deterioration along the experiment-route.

Figure 3. Mapping report of damage classification

4. CONCLUSIONS

This paper introduced the proof of concept results of the automatic classification of superficial asphalt deterioration by acoustic feature extraction and pattern recognition approach.

The 1/3 octave filter bank applied to the audio frames shows an important source of information to contribute the detection of asphalt surface deterioration. The conformed data let us to implement a machine learning model based on Nearest Neighbors classifier with an average accuracy greater than 92%. Since the classification of road segments is wholly depending of the exact tyre/road contact zone, it is the reason why many car-pass are necessary to contemplate the maximum analyzed road- surface.

To achieve an extensive dataset, the exploitation of acoustical data could be earned with collaborative instrumented cars, traveling along different routes and storing noise-data from different scenarios and conditions. This will certainly improve the automatic inspection of road facilities with low cost electroacoustic setup.

The advantage of this approach is the possibility of using conventional vehicles that are involved in other everyday urban tasks (taxis, police cars, buses, etc.) to track the state of the asphalt, while driving their normal routes. Consequently, the implementation of exclusively road surface inspection vehicles would become unnecessary and the related costs would be reduced. Also, the autonomous vehicles can be benefit of this approach to improve the awareness situation while driving.

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