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Conference Abstract

Sensitivity Analysis of Bicycle Characteristics for Pavement Roughness Monitoring by Vibration Data

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Abstract

Introduction: Promoting cycling, both as a mode of transport and as an integrating element of other forms of urban mobility, is a key part of making cities sustainable. Vibration caused by lack of pavement maintenance affects the comfort, health and safety of cyclists and has been identified as one of the main infrastructural barriers to cycling. The focus of this paper is to investigate how the physical characteristics of bicycles affect the vibration response under different pavement conditions, and to explore the potential of crowdsourced collection with sensor-equipped bicycles to collect data for road condition and comfort assessment of micro-mobility users.
The organization of the paper follows the research development based on 3 main tasks:

1) Experimental data collection of vibration and pavement characteristics
2) Numerical modeling and genetic algorithm to identify the mechanical configuration of the test bicycle to match the experimental data.
3) Sensitivity analysis to study how the variability in bicycle characteristics contributes to the overall uncertainty in multiple measurements.

Materials and Methods: An experiment was conducted in which an equipped bicycle was used to collect vertical accelerations at different speeds, and an advanced laser profiler and laser crack measurement system (LCMS) was used to model the pavement surface in the travel path. Vertical acceleration data with GNSS coordinates, along with pavement longitudinal profiles and distresses, were collected with several runs at different speeds on selected test roads.
Various pre-processing steps were then applied to synchronize the data collected by smartphone and mobile laboratory. The vertical accelerations recorded in the field were filtered and synchronized to ensure comparability with the simulation carried out on the actual profile of the pavement roughness. The road profile was used as input to simulate the vehicle dynamics with a half car model in MATLAB Simulink. Given a road profile and running speed, in the half-car model, the acceleration signal is affected by the 6 bicycle dynamic parameters related to stiffness and damping factors (kt1-2, k1-2 and c1-2). Different settings of the bicycle parameters change the goodness of fitting between measured and simulated RMSs. Due to the complexity of the system and the number of variables, we implemented a genetic algorithm (GA) to identify the model parameters that minimize the difference between simulated and measured RMS. Therefore, the mathematical formulation based on the half-car relaxation model was integrated in a genetic algorithm optimization process to identify the bike parameters which minimize the error between the simulated and in-field Root Mean Square (RMS) of vertical accelerations. The optimization aimed to ensure the model parameters' best consistency with the real dynamic response of bicycle to road profiles.

Results and Conclusion: The sensitivity analysis was carried out by varying the bicycle characteristics in the range of values that can be expected in real world data collection from several bicycle types. The sensitivity analysis was performed to investigate how the variability from the best fitting bicycle parameters contributes to the overall uncertainty in the vibration response over repeated measurements. For the proposed sensor configuration and speed range, the sensitivity analysis showed the relative relevance of the bicycle characteristics when compared to the overall accuracy of the results effected by the position of the bicycle path over the variability of the road surface. As further practical information, the results confirmed the opportunity to apply different data analyses for the detection of pavement anomalies such as potholes, bumps and high severity linear cracks based on the RMS of the peaks. The average RMS data, cleansed of outliers, can be used to assess rider comfort as well as different types of pavement distress such as alligator cracking, moderate linear cracking and bumps.

Keywords: Bicycle, Road Pavement, Vibration, Genetic Algorithm

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